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BEN SMITH, FORMER CIA OPERATIVE

"THERE IS NO TERRESTRIAL ORIGIN"

LT COL KEVIN D. RANDLE, US ARMY RESERVE

THE TRUTH ABOUT THE ROSWELL FILES

HOW INVESTIGATIONS BY A FORMER CIA OPERATIVE DISPROVE THE FLYING SAUCER CONSPIRACY THEORY

+
RARE SUPERNOVA
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Issue 116

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This month we delve deep into an incident that occurred on a ranch in Lincoln County, New Mexico, in 1947 - an event that is a mix of rumours, speculation and claims of debris from a spaceship and alien bodies: the Roswell UFO incident.

Over the past 40 or so years, new claims and fresh leads suggest that what happened that summer wasn't of terrestrial origin. "I found all this stuff, and I was told to keep my mouth shut," said Major Jesse A. Marcel, who was sent to survey the crash site. "I held on to this premium for 32 years without saying anything at all. See, I was an intelligence officer. I handled intelligence and security for the base. I still hold an allegiance to my country, the vow that I took to keep my mouth shut about everything that might encroach on military secrets."

But what really happened at Roswell? This issue, **All About Space** uncovers what the likely explanation is with the help of psychologist Ken Drinkwater, who specialises in the anomalous and paranormal. Turn to our lead feature for our reveal - I can't wait for you to discover more!

Also in this issue, we enter the world of wormholes and a new way of detecting them, provide you with an update on Perseverance, reveal the plans for the Chinese Space Station and much more. See you soon!

GEMMA LAVENDER

EDITOR-IN-CHIEF

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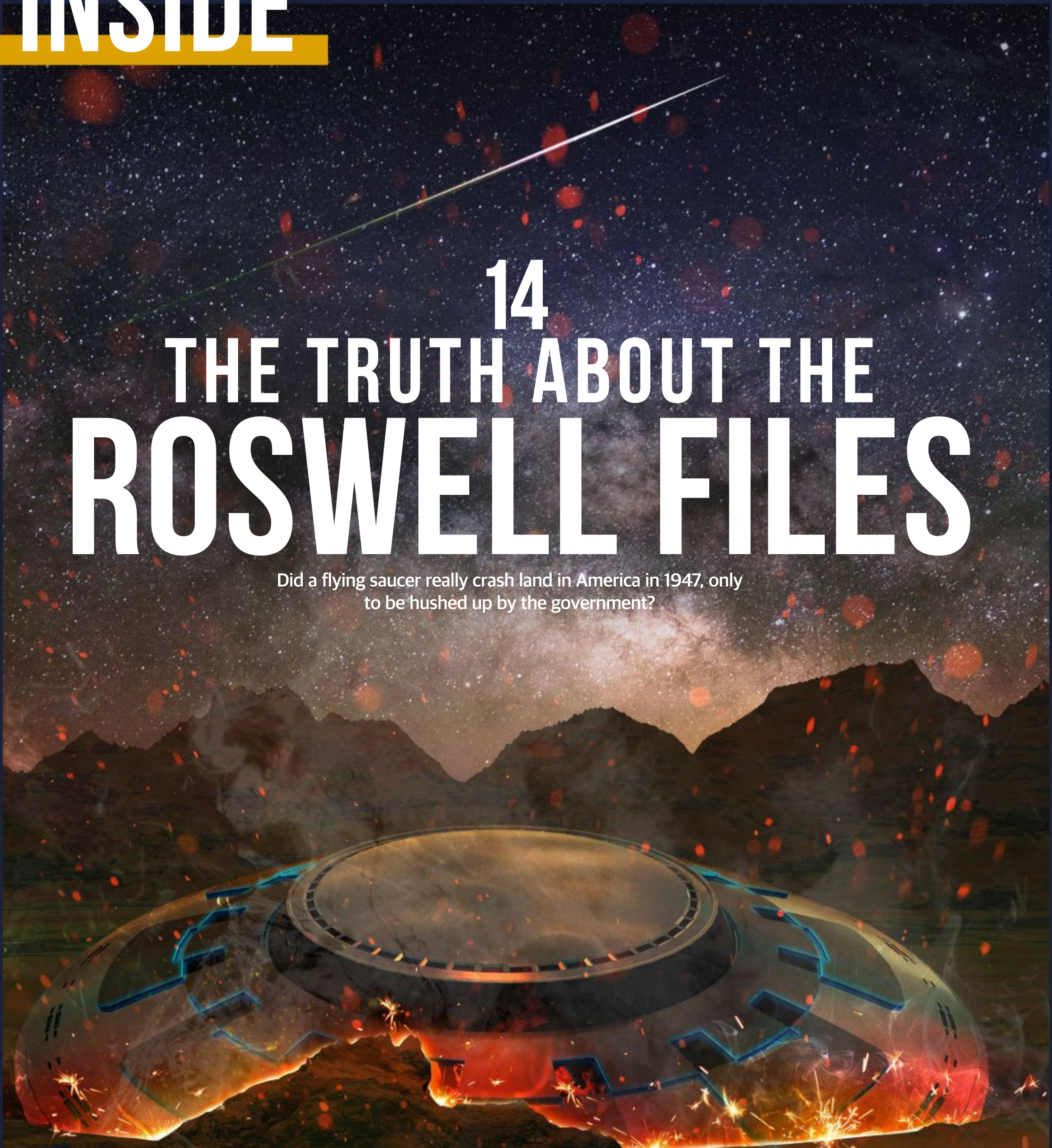

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Did a flying saucer really crash land in America in 1947, only to be hushed up by the government?

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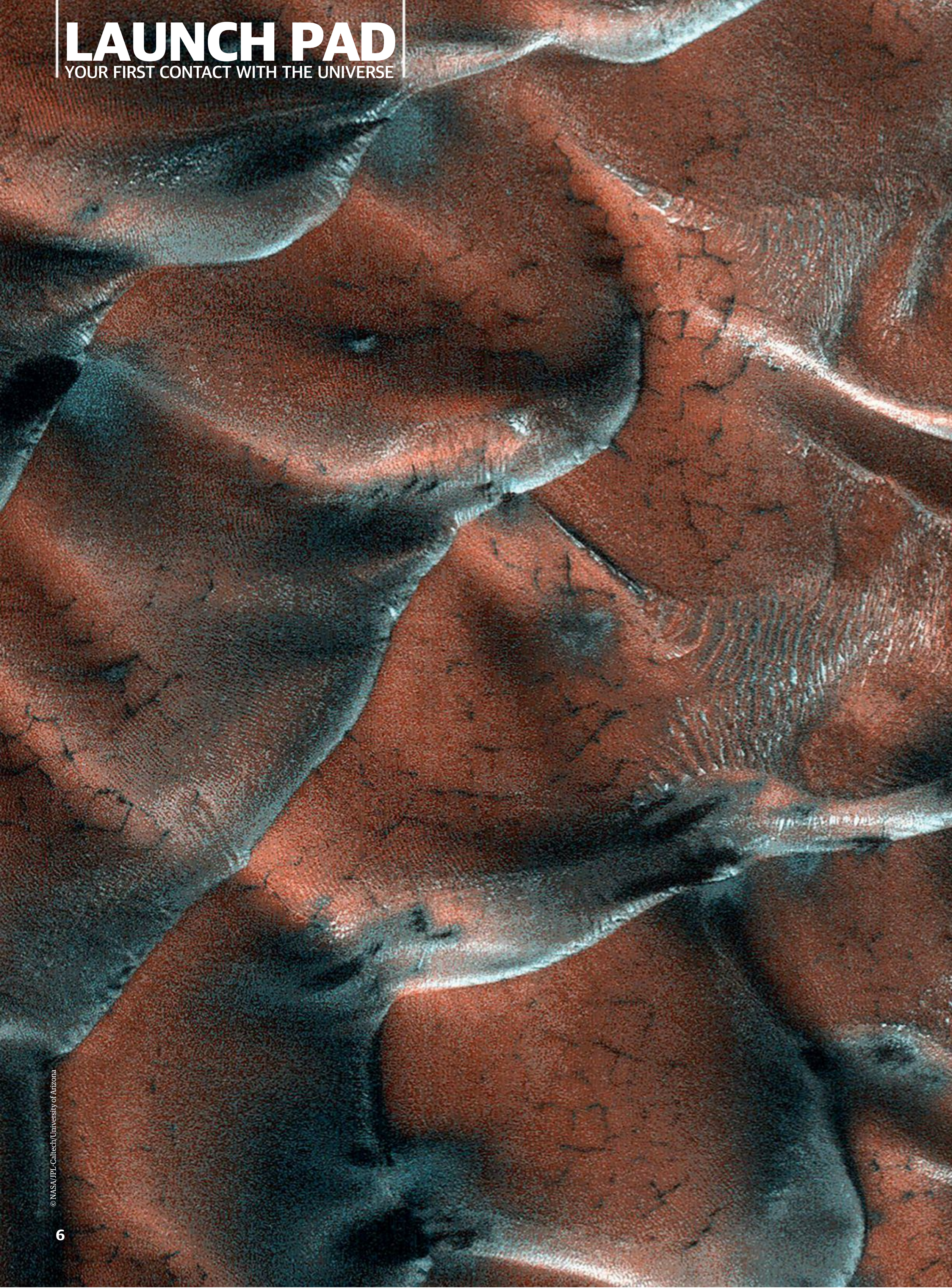

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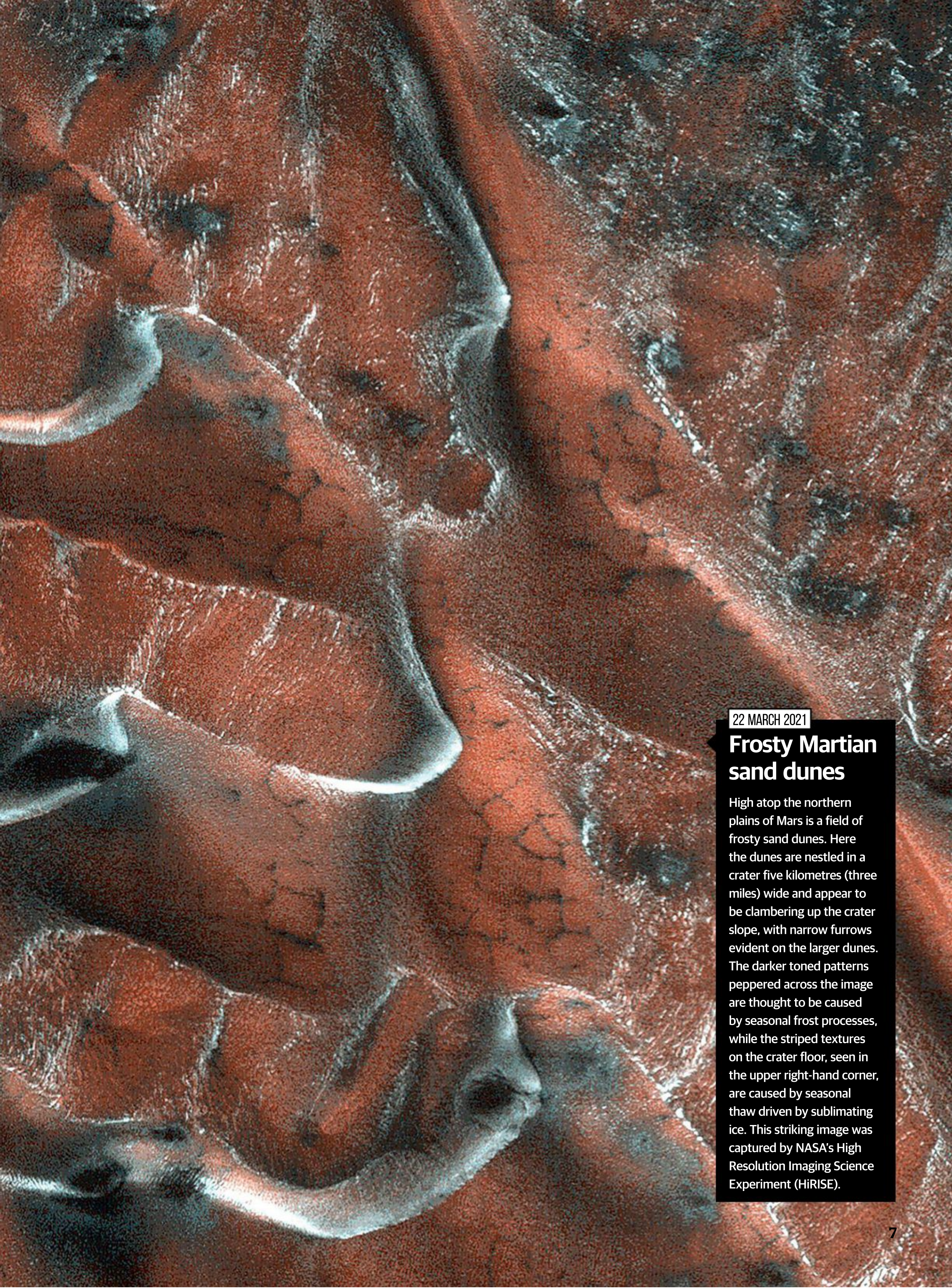


22 MARCH 2021

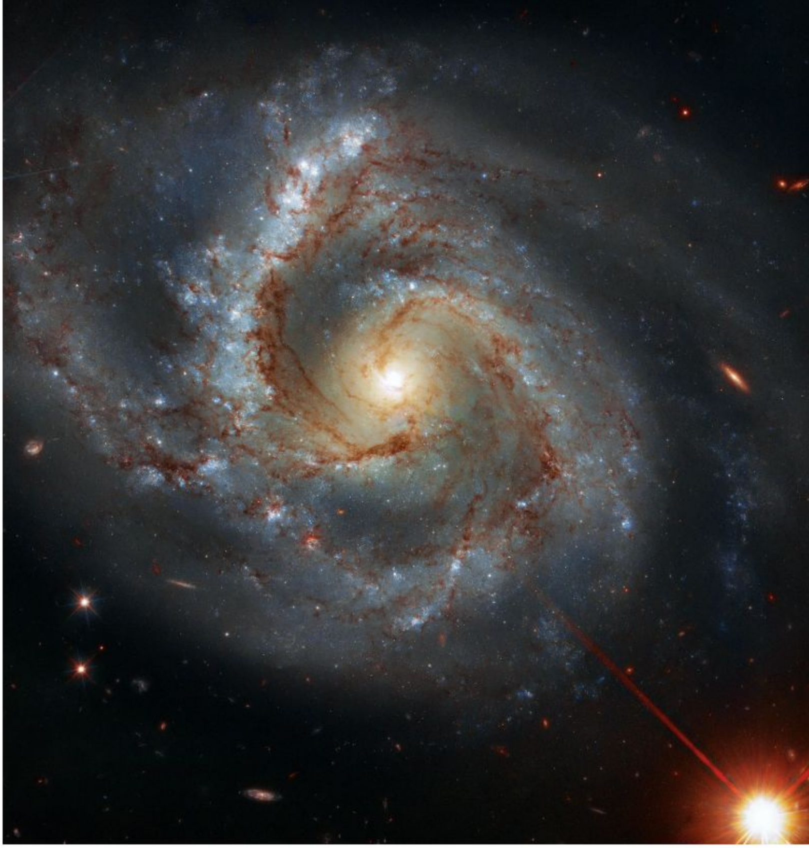
Frosty Martian sand dunes

High atop the northern plains of Mars is a field of frosty sand dunes. Here the dunes are nestled in a crater five kilometres (three miles) wide and appear to be clambering up the crater slope, with narrow furrows evident on the larger dunes. The darker toned patterns peppered across the image are thought to be caused by seasonal frost processes, while the striped textures on the crater floor, seen in the upper right-hand corner, are caused by seasonal thaw driven by sublimating ice. This striking image was captured by NASA's High Resolution Imaging Science Experiment (HiRISE).

22 MARCH 2021

A peculiar galaxy

NGC 7678 is a dazzling spiral galaxy that lies approximately 164 million light years away in the constellation of Pegasus (the Winged Horse). It was discovered in 1784 by William Herschel and measures around 115,000 light years across, making it similar in size to the Milky Way. Everything about the galaxy appears 'normal' at first glance, so why has it earned itself a place in *The Atlas of Peculiar Galaxies*? Here you can find NGC 7678 catalogued as Arp 28, where it is listed in the group 'spiral galaxies with one heavy arm'.



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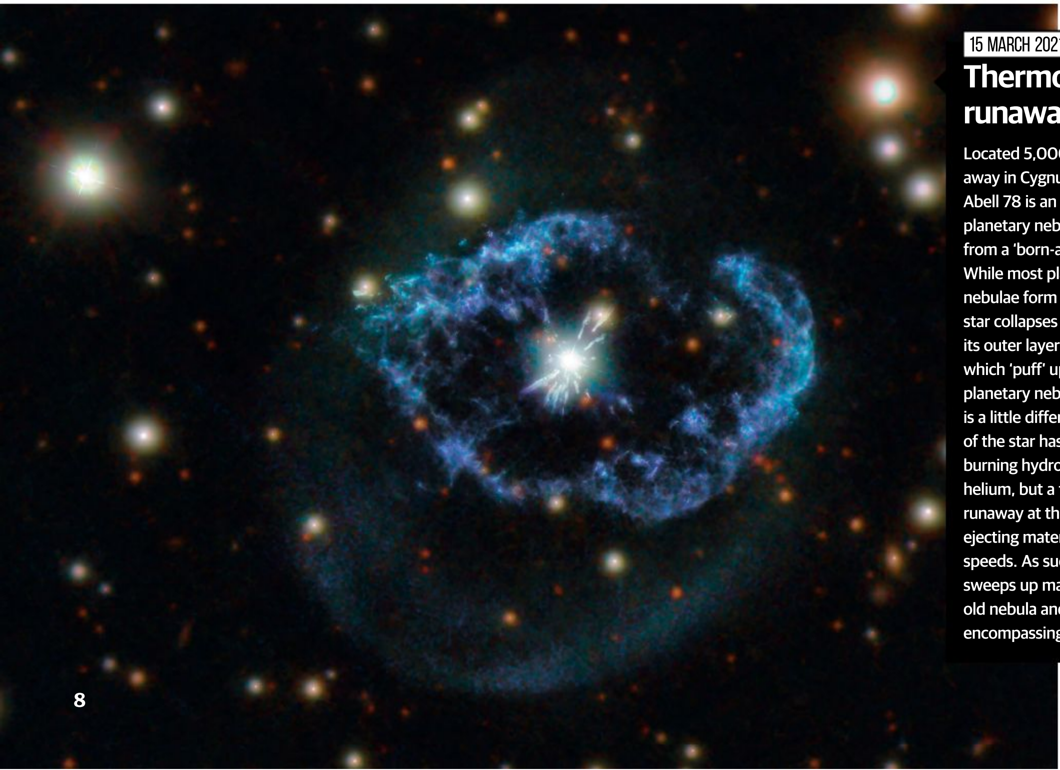

15 MARCH 2021

Thermonuclear runaway

Located 5,000 light years away in Cygnus (the Swan), Abell 78 is an unusual planetary nebula resulting from a 'born-again' star. While most planetary nebulae form when a dying star collapses and expels its outer layers of material, which 'puff' up into a planetary nebula, Abell 78 is a little different. The core of the star has long stopped burning hydrogen and helium, but a thermonuclear runaway at the surface is ejecting material at high speeds. As such, the ejecta sweeps up material from the old nebula and produces the encompassing blue shell.

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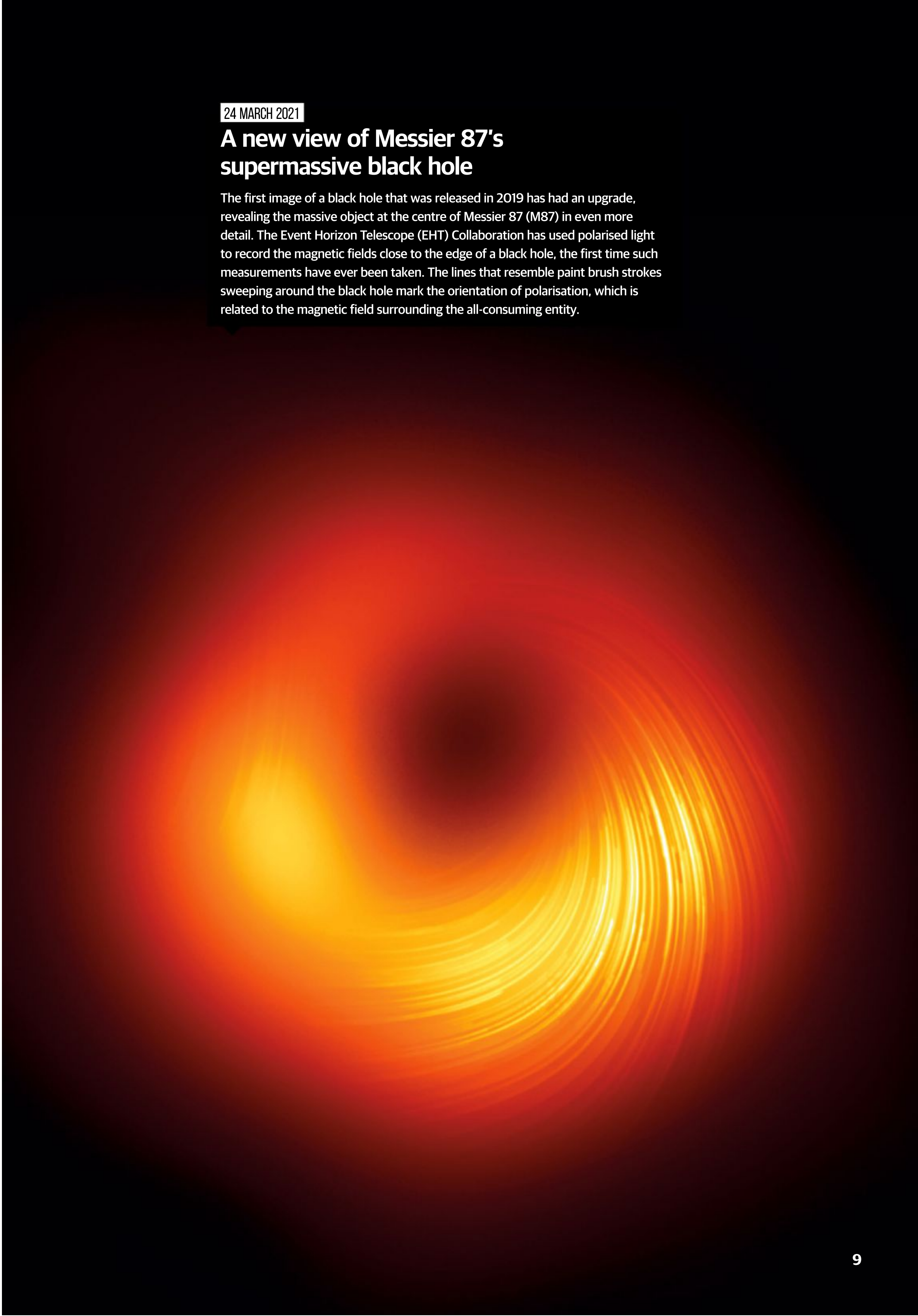
24 MARCH 2021

A new view of Messier 87's supermassive black hole

The first image of a black hole that was released in 2019 has had an upgrade, revealing the massive object at the centre of Messier 87 (M87) in even more detail. The Event Horizon Telescope (EHT) Collaboration has used polarised light to record the magnetic fields close to the edge of a black hole, the first time such measurements have ever been taken. The lines that resemble paint brush strokes sweeping around the black hole mark the orientation of polarisation, which is related to the magnetic field surrounding the all-consuming entity.



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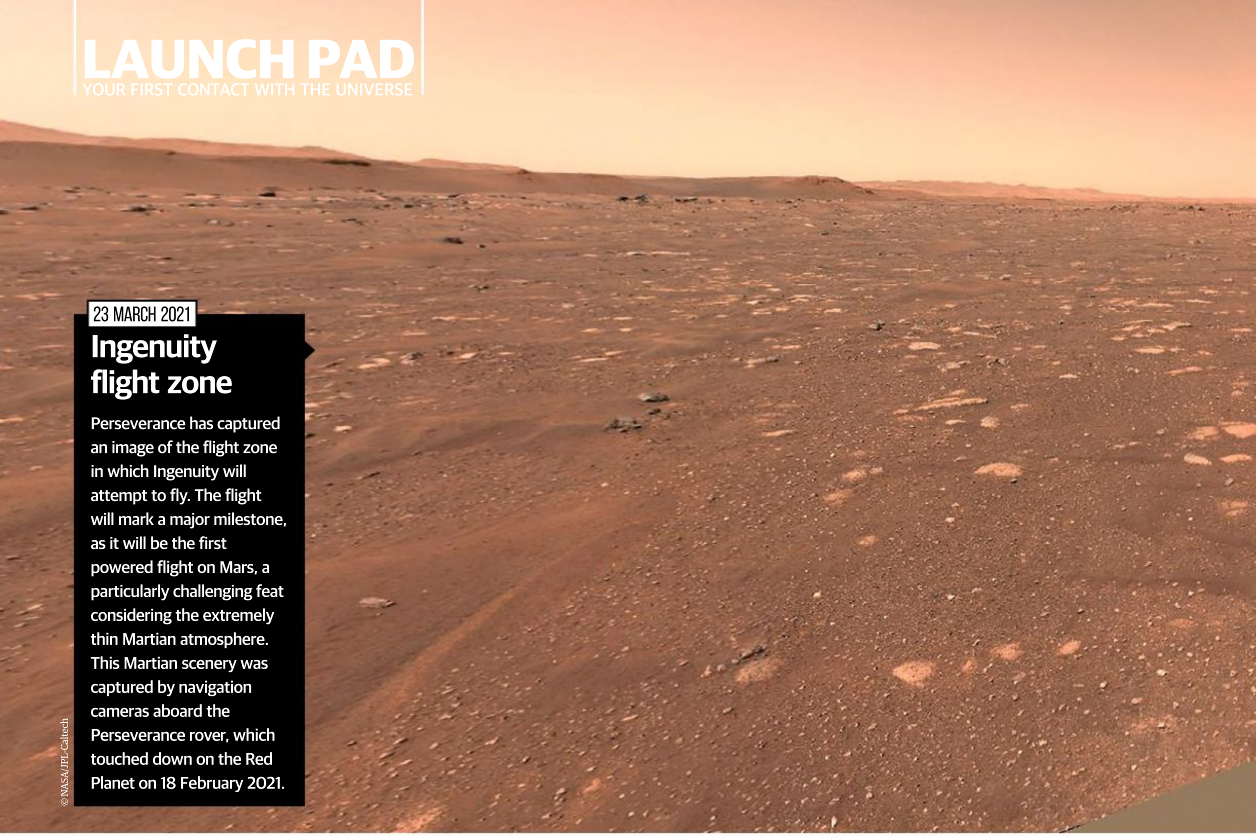

23 MARCH 2021

Ingenuity flight zone

Perseverance has captured an image of the flight zone in which Ingenuity will attempt to fly. The flight will mark a major milestone, as it will be the first powered flight on Mars, a particularly challenging feat considering the extremely thin Martian atmosphere. This Martian scenery was captured by navigation cameras aboard the Perseverance rover, which touched down on the Red Planet on 18 February 2021.

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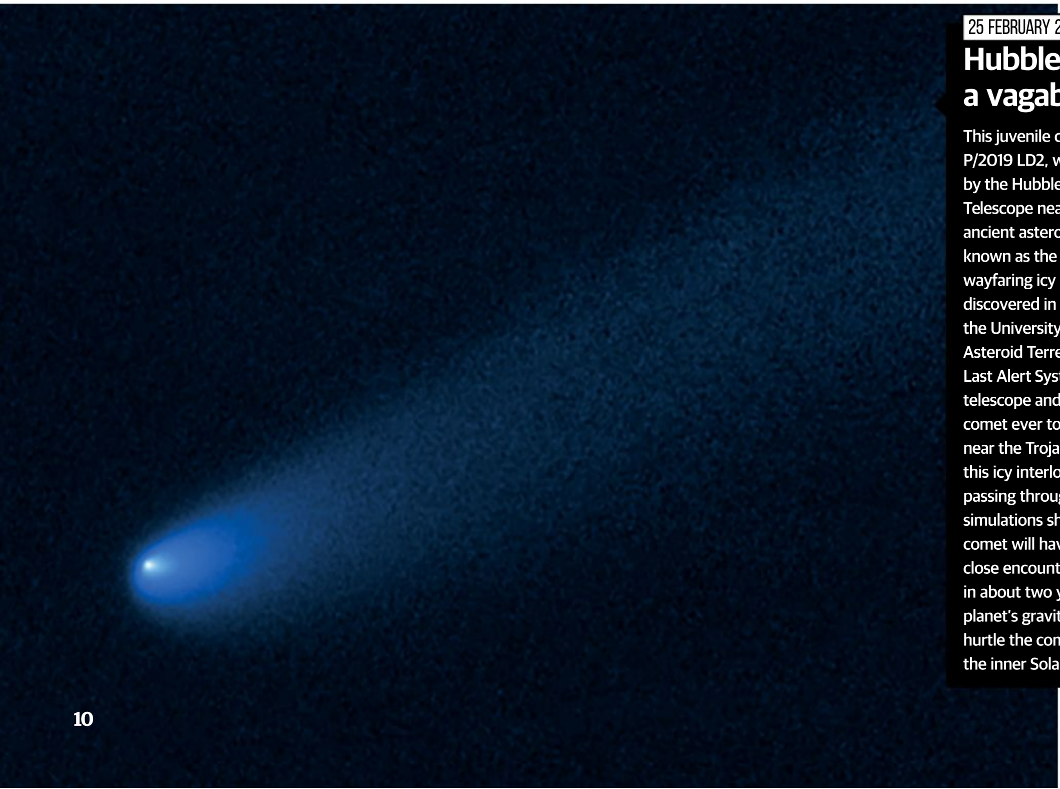

25 FEBRUARY 2021

Hubble spots a vagabond

This juvenile comet, P/2019 LD2, was spotted by the Hubble Space Telescope near Jupiter's ancient asteroid population known as the Trojans. The wayfaring icy body was discovered in June 2019 by the University of Hawaii's Asteroid Terrestrial-impact Last Alert System (ATLAS) telescope and is the first comet ever to be observed near the Trojans. However, this icy interloper is merely passing through – computer simulations show the young comet will have a rather close encounter with Jupiter in about two years. The planet's gravity will then hurtle the comet towards the inner Solar System.

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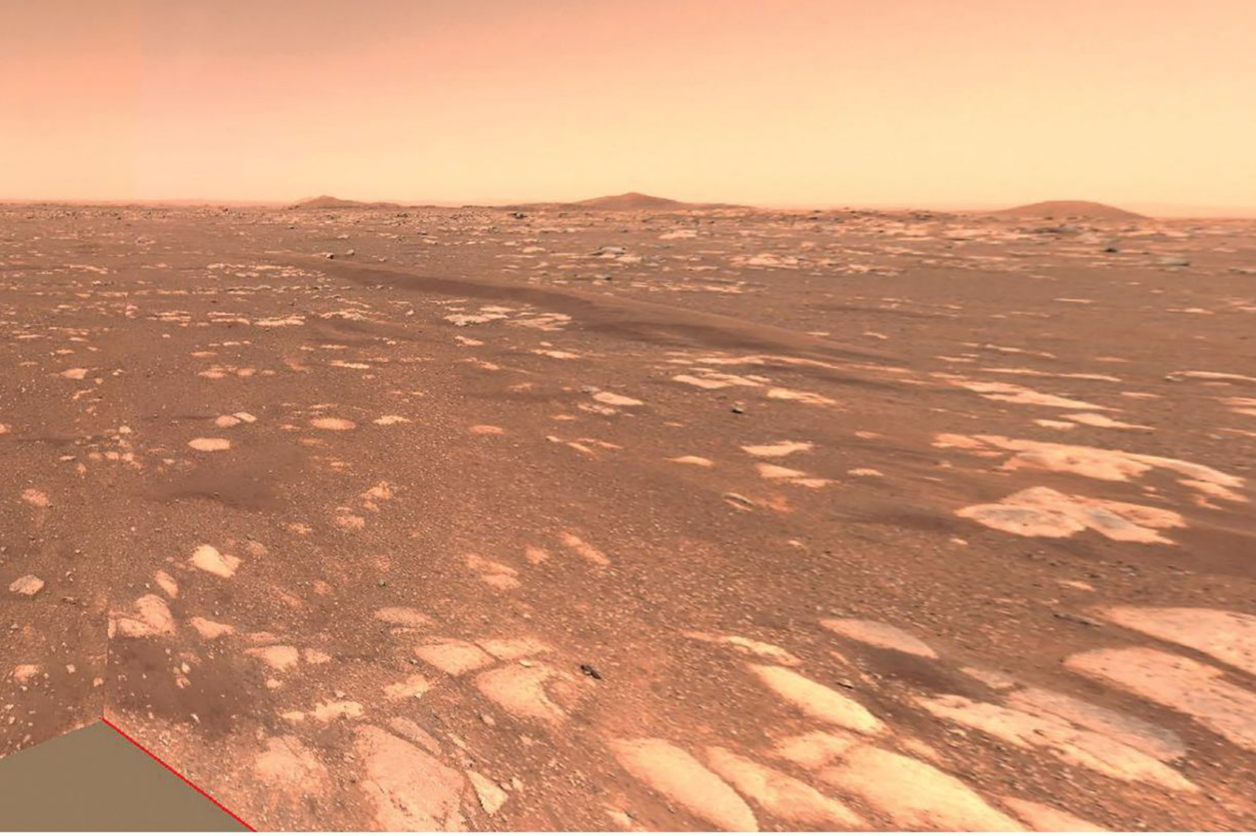

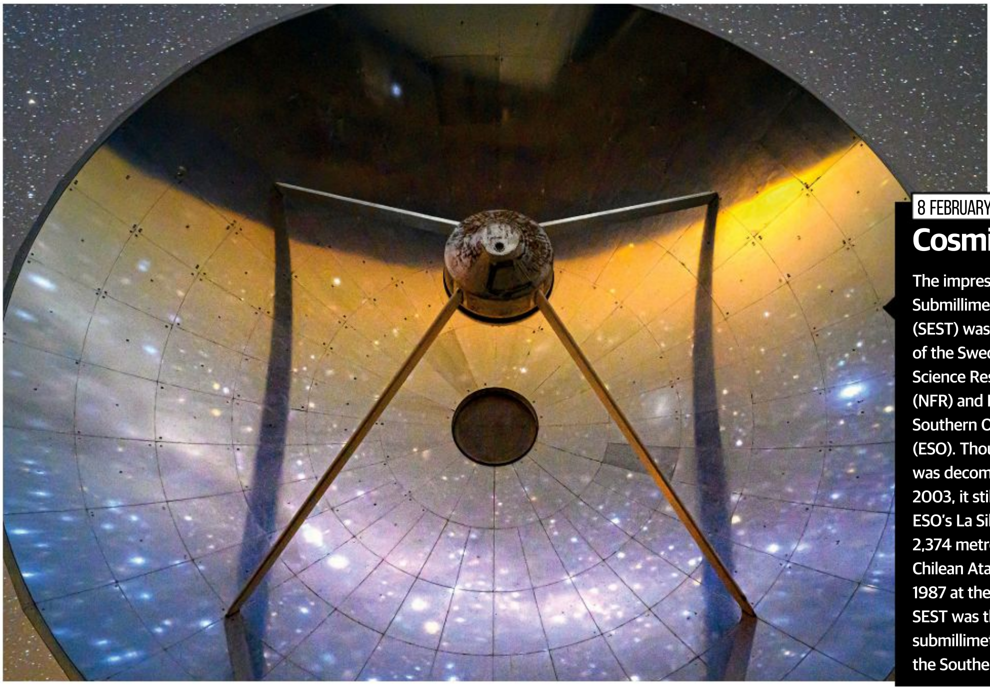

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8 FEBRUARY 2021

Cosmic dish

The impressive Swedish-ESO Submillimetre Telescope (SEST) was built on behalf of the Swedish National Science Research Council (NFR) and European Southern Observatory (ESO). Though the telescope was decommissioned in 2003, it still stands tall at ESO's La Silla Observatory, 2,374 metres high in the Chilean Atacama Desert. In 1987 at the time of first light, SEST was the only large submillimetre telescope in the Southern Hemisphere.

The black hole could be influenced by an invisible companion

A supermassive black hole is speeding through space, and astronomers don't know why

Words by Ben Turner

A supermassive black hole is racing across the universe at 177,000 kilometres (110,000 miles) per hour, and the astronomers who spotted it don't know why. The fast-moving black hole, which is roughly 3 million times heavier than our Sun, is zipping through the centre of a galaxy about 230 million light years away.

Scientists have long theorised that black holes could move, but such movement is rare because their giant mass requires an equally enormous force to get them going. "We don't expect the majority of supermassive black holes to be moving; they're usually content to just sit around," said Dominic Pesce, an astronomer at the Harvard-Smithsonian Center for Astrophysics.

To begin their search for this infrequent cosmic occurrence, researchers compared the velocities of ten supermassive black holes with the galaxies they formed the centre of, focusing on the black holes with water inside their accretion discs - the spiral-shaped collections of cosmic material in orbit around the black holes. Why water? As water orbits a black hole, it collides with other material, and the electrons surrounding the hydrogen and oxygen atoms that make up water molecules get excited to higher energy levels. When these electrons return to their ground state, they emit a beam of laser-like microwave radiation called a maser. By taking advantage of a cosmic phenomenon known as redshift, in which objects moving away have their light stretched to longer wavelengths, the astronomers were able to observe the extent to which the maser light from the accretion disc was shifted away from its known frequency when stationary, thereby gauging the speed of the moving black hole.

They took more observations from various telescopes and combined them all together using a technique called very-long-baseline interferometry. With this technique, the researchers could combine the images from several telescopes to effectively act like an image captured by a very big telescope, about the size of the distance between them. In that way the scientists could precisely measure the velocity of the black holes it originated from.

The researchers don't know what could have made such a heavy object move at such a high speed, but they came up with two possibilities. "We may be observing the aftermath of two supermassive black holes merging," said Jim Condon, a radio astronomer at the National Radio Astronomy Observatory, "The result of such a merger can cause the newborn black hole to recoil, and we may be watching it in the act of recoiling or as it settles down again." The other possibility is considered to be much rarer and more novel: the supermassive black hole may be part of a pair with another black hole that's invisible to measurements. If the black hole is being tugged around by an even bigger invisible one, this could explain why it's travelling so fast, but more observations will be needed to get to the bottom of the mystery.

Mars is leaking water into space during dust storms and warmer seasons

Words by Chelsea Gohd

Water is leaking from Mars' atmosphere through changing seasons and swirling Martian storms. There is water on Mars, but it seems to only exist either in ice caps at the planet's poles or as gas in the thin atmosphere. Water has been escaping the planet for billions of years since Mars lost its magnetic field - and subsequently much of its air and water. Researchers using data from the European Space Agency's (ESA) ExoMars orbiter and Mars Express orbiter are investigating the escape rate of Mars' water. They've found that when Mars and the Sun are farther apart, the cold makes the water vapour at a certain altitude in Mars' atmosphere freeze out, but as the planet gets closer and warmer, that water can circulate farther. As vapour can travel out farther in Mars' atmosphere during warmer seasons, those are also the times when the planet loses more water.

But it's not just seasons that dictate how much of Mars' water leaks out into space; dust storms also play an important role. Scientists have found that in the years that Mars experienced global dust storms, water travelled higher in the planet's atmosphere. In these years, water vapour is found over 80 kilometres (50 miles) from the planet's surface. Scientists have found that every billion years, Mars loses the equivalent of a global two-metre (6.5-foot) layer of water.

© NASA/JPL-Caltech

Above: Water vapour is found higher up in warm weather

Astronomers find most distant quasar shooting powerful radio jets

Words by Chelsea Gohd

A quasar from the early universe is the most distant found to date that's shooting out powerful radio jets. Astronomers using the European Southern Observatory's (ESO) Very Large Telescope (VLT) recently discovered the quasar, called P172+18, which is so far away that it takes about 13 billion years for the light from this quasar to reach Earth, where we observe the object as it was when the universe was just 780 million years old. While the new find is not the most distant quasar ever detected, it appears to be the most distant radio-loud quasar, or radio jet-emitting quasar.

This quasar was first identified as a radio source when scientists using the Magellan Telescope at Las Campanas Observatory in Chile detected these powerful jets. "As soon as we got the data, we inspected it by eye, and we knew immediately that we had discovered the most distant radio-loud quasar known so far," said Eduardo Bañados of the Max Planck Institute for Astronomy in Germany, who led this discovery alongside ESO astronomer Chiara Mazzucchelli.

The distant jet-shooting quasar is powered by a supermassive black hole that's about 300 million times more massive than our Sun and is growing quickly, pulling in and swallowing surrounding matter with its immense gravity. The researchers think that there could be a connection between the quick growth of black holes like this and the jets that shoot out of radio-loud quasars like P172+18. These powerful jets might interact with nearby gases in a way that pushes the gases into the gravitational grip of these black holes, increasing how much gas falls into them.

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Left: ESO scientists discovered the radio source was a distant quasar

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Jupiter's Great Red Spot may survive by gobbling up smaller storms

Words by Mike Wall

The most famous storm in the Solar System is an apex predator. Jupiter's Great Red Spot (GRS) feasted on numerous smaller storms that wandered into its neighbourhood recently, possibly even gaining sustenance from these meals. Astronomers have been observing the Great Red Spot continuously since the late 19th century. The storm has shrunk considerably during that stretch, going from 40,000 kilometres (25,000 miles) wide in the 1870s to about 16,000 kilometres (10,000 miles) wide today. Astronomers aren't sure why the GRS is getting smaller. Some have speculated that collisions with smaller storms, which have increased in recent years, may play a role.

Scientists have studied images of the GRS captured between 2018 and 2020 by NASA's Hubble Space Telescope, the space agency's Jupiter-orbiting Juno spacecraft and amateur astronomers here on Earth. They have identified numerous encounters between the GRS and smaller anticyclones - these swirl around central cores of high atmospheric pressure, whereas cyclones such as Earth's hurricanes spin around regions of low pressure.

These atmospheric crashes chipped away at the GRS, peeling off cloud chunks around the big storm's edges. The GRS' diameter shrank as it gobbled up these smaller storms, but those changes were likely only skin-deep, "not affecting the full depth of the GRS," said Agustin Sánchez-Lavega, a professor of applied physics at the University of the Basque Country in Spain, and his team.

"The interactions are not necessarily destructive, but can transfer energy to the GRS, maintaining it in a steady state and guaranteeing its long lifetime," they added.

© NASA

Above: The GRS is the biggest storm in the Solar System

Russia and China just agreed to build a research station on the Moon together

Words by Mike Wall

Leaders of the China National Space Administration (CNSA) and Roscosmos, Russia's space agency, signed a memorandum of understanding on 9 March on the construction of a Moon outpost called the International Lunar Research Station (ILRS). "The ILRS is a comprehensive scientific experiment base with the capability of long-term autonomous operation, built on the lunar surface and/or lunar orbit that will carry out multi-disciplinary and multi-objective scientific research activities such as lunar exploration and utilisation, lunar-based observation, basic scientific experiments and technical verification," said CNSA officials.

The CNSA announcement did not provide a targeted timeline for the lunar research station, nor did a similar release put out by Roscosmos. The United States is currently working on its own ambitious Moon push with NASA's Artemis program. The agency has inked deals with numerous partners in the private sector, and eight other nations have signed the Artemis Accords, clearing the way for their participation in the program. Russia and China are not among the signatories.

Russia has worked extensively with the US in space, most notably on the International Space Station program, but Roscosmos chief Dmitry Rogozin recently said that the nation is unlikely to be an Artemis partner. China cannot participate substantially in the NASA Moon push, at least not without new US legislation. Since 2011, NASA and the White House Office of Science and Technology Policy have been prohibited from cooperating on space projects with their Chinese counterparts unless Congress approves such cooperation in advance.

Left: A new space race to build a moonbase may begin soon

Russian scientists deploy giant telescope beneath Lake Baikal

Words by Stephanie Pappas

The telescope, Baikal-GVD, is designed to search for neutrinos, which are nearly massless subatomic particles with no electrical charge. Neutrinos are everywhere, but they interact so weakly with the forces around them that they're challenging to detect. That's why scientists are looking under Lake Baikal, which is the deepest lake on Earth.

Neutrino detectors are typically built underground to shield them from cosmic rays and other sources of interference. Clear freshwater and thick, protective ice cover make Lake Baikal an ideal place to search for neutrinos.

Scientists deployed the detector through the ice in the southern part of the lake on 13 March, lowering modules made of string, glass spheres and stainless steel up to 1,310 metres (4,298 feet) into the water. The spheres hold photomultiplier tubes, which detect a particular kind of light that's given off when a neutrino passes through a clear medium at a speed faster than light travels through the medium.

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Right: The deep lake in Siberia is a perfect hunting ground for neutrinos

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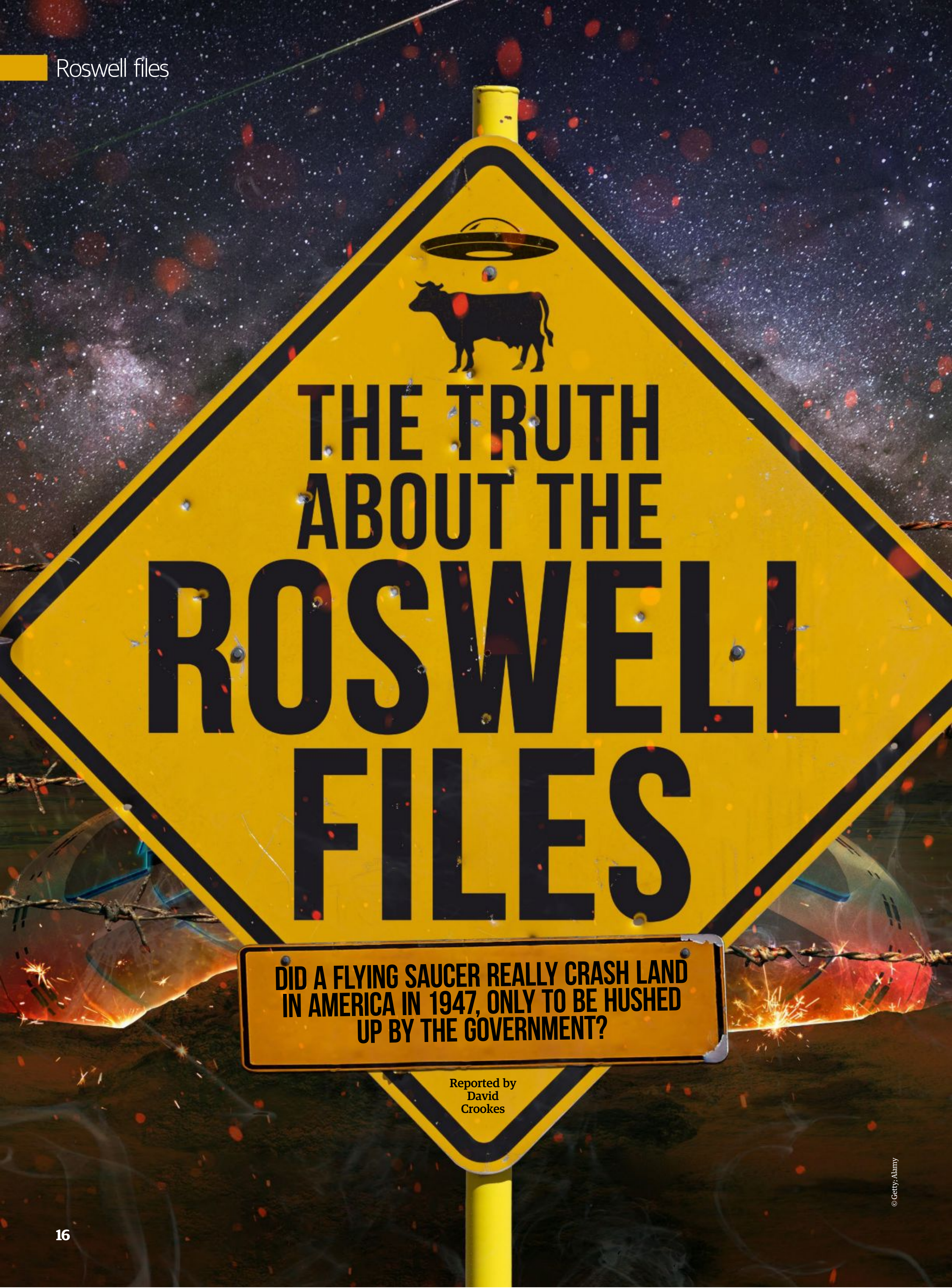

THE TRUTH ABOUT THE ROSWELL FILES

DID A FLYING SAUCER REALLY CRASH LAND IN AMERICA IN 1947, ONLY TO BE HUSHED UP BY THE GOVERNMENT?

Reported by
David
Crookes

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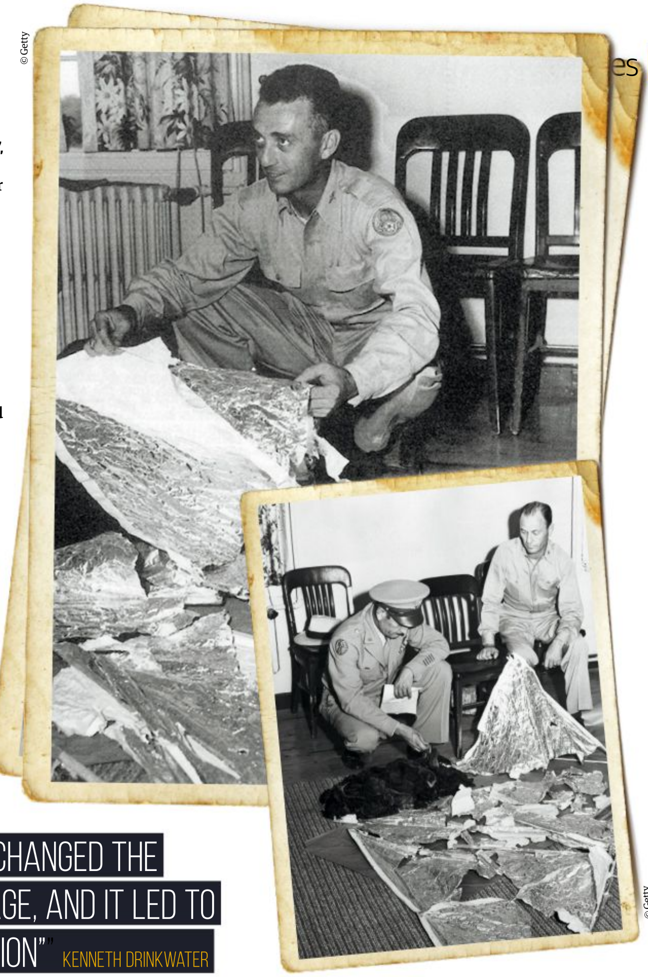
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Right: In 1947, Brigadier General Roger M. Ramey and Colonel Thomas J. Dubose identified fragments found by the rancher as pieces of a weather balloon. The story changed in 1994, however

> "THEY CHANGED THE MESSAGE, AND IT LED TO SUSPICION" KENNETH DRINKWATER

There is a spaceship that looks like a flying saucer in Roswell. Thousands of motorists drive past it every day, and hundreds of people pop inside. It's on North Main Street in this southeastern New Mexico city, its metal skin gleaming as it basks in the glow of the Sun. Its neon lighting burns into the retinae of those who view it throughout the evening, and it's rather hard not to admire it. After all, quite aside from its striking looks, who doesn't fancy a burger every now and then? This spacecraft is one of the city's McDonald's restaurants, and the reason why the building is shaped that way? It's not that far from the site of a mysterious incident which took place in 1947 - the day when a rancher discovered debris scattered around his sheep pasture, prompting speculation a UFO had crashed there.

William Brazel had woken for a normal day's work on the J. B. Foster ranch in Lincoln County, New Mexico, 120 kilometres (75 miles) north of Roswell. It was sometime in June, or maybe the first few days of July in 1947, and he was shocked to find "a large area of bright wreckage made up of rubber strips, tinfoil, a rather tough paper and sticks," to quote his words at the time.

Brazel hadn't heard of flying saucers. At least not yet. Sightings, however, were coming in thick and fast around that time. On 24 June pilot Kenneth Arnold claimed to see nine unidentified objects "flying like a saucer would" near Mount Rainier, Washington. Arnold estimated that the objects were flying at around 1,930 kilometres (1,200 miles) per hour, but at the time there were no known craft that could reach those speeds. The Air Force also said it had no new experimental planes or guided missiles which would fit such a description.

Even so, the US soon became gripped, as Brazel discovered. By 7 July, policemen and astronomers were reportedly being harassed for further reports, this time over in New York and other Eastern states, and that was the day Brazel decided to take action. He hand-delivered a box of accumulated debris, which he'd gathered with the help of his wife and two children, to sheriff George Wilcox of Roswell.

By now there was talk of a reward for anyone who recovered one of these unidentified flying objects. Brazel "whispered kinda confidential-like" that his find may be one of the flying discs, so an equally intrigued Wilcox contacted Colonel William Blanchard, the commanding officer of the Roswell Army Air Field (RAAF), who sent agents to the site to gather the remaining material.

What happened next would cement the idea that the debris was the remnants of an alien spacecraft. The RAAF's public information officer Walter Haut issued a press release on 8 July: "The many rumours regarding the flying disc became a reality yesterday when the intelligence office of the 509th Bomb Group of the Eighth Air Force, Roswell Army Air Field, was fortunate enough to gain possession of a disc through the cooperation of one of the local ranchers and the sheriff's office of Chaves County."

This was reported in the *Roswell Daily Record* along with the news that Major Jesse A. Marcel was the group intelligence officer dispatched to the scene. He'd gone with Counter Intelligence Corps officer Sheridan Cavitt, but on his way back took a detour to his own home, whipped out a couple of boxes of debris that he'd popped into the boot of his car and showed it to his ten-year-old son, Jesse Jr. One of the objects was said to have hieroglyphic-like markings, something that stuck in the mind of the young boy.

Yet just as quickly as excitement of the find gathered pace, so the US Army took swift action in debunking the story. Indeed, the very next day, shortly after government scientists began to arrive at the scene, it was claimed that the debris was actually from a crashed weather balloon, and Marcel was asked to be pictured at a press conference with the debris allegedly found. And that was that. Case closed… or so everyone thought.

But around 1978, interest began to grow again. Nuclear physicist, author and UFO researcher Stanton Friedman interviewed Marcel, who said that the discovery made 31 years earlier was not from this world and that the government had ordered him to keep quiet. Friedman revisited the incident and sought other witnesses, with his work inspiring Charles Berlitz and William Moore to write *The Roswell Incident*, published in 1980. Their conclusion was simple: there had been a huge cover-up. There was no going back.

Other things were happening in the world at this time. Notably, the sci-fi films *Star Wars* and *Close Encounters of the Third Kind* had just been released, and there have been studies since that suggested sightings and belief in UFOs rise when popular films and TV shows make their debut. Nevertheless, testimonies about that day in 1947 were forthcoming, and they continued to come for many years.

Glenn Dennis called a hotline shortly after an episode of *Unsolved Mysteries* featuring the Roswell incident was aired in the US in 1989. He went further and suggested that a friend who worked as a nurse at the Roswell Army Air Field saw three alien bodies. But the real bombshell moment came

WHAT HAPPENED?

Who knows what actually crashed in 1947? All we know is that something ended up on the ground near Roswell

1 Crash landing

Rancher William Brazel discovered strange-looking debris scattered across his ranch sometime after 14 June. Whatever it was, everyone has since agreed that something crashed overnight.

2 Examining the wreckage

Having pondered his find, Brazel took his family to look at the wreckage to see what they made of it. There were also reported sightings of UFOs across the United States.

3 Reporting the find

Brazel reported the find to the police sheriff of Roswell, driving over to the police station to show evidence of some debris. The army was then informed of the incident.

4 Gathering some debris

Major Marcel was sent to the scene along with Lieutenant Colonel Cavitt to gather evidence. When they returned, there was a suggestion that the items were not of this Earth.

5 Press release issued

A statement was issued suggesting that a 'flying disc' had been found, and this was what was reported by the media. It caught people's imagination, and there was great interest in the incident.

© Nicholas Forder

in 1994. This is when the US Air Force admitted the weather balloon story was untrue after all. Could it be that the debris really was from an alien craft?

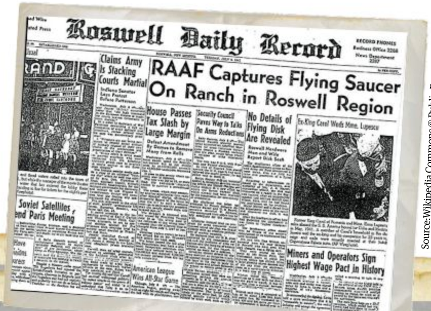
According to the US Air Force, no. It had made up the weather balloon story, but it wasn't to hide the fact that little green men had visited Earth. The wreckage was actually that of a classified project that flew microphones on high-altitude balloons so that sound waves generated by Soviet atomic bomb tests could be detected. Called Project Mogul, it was said to have run between 1947 and 1949. What's more, the balloons were claimed to have been made up of unusual material – the type that could easily be confused for a UFO. Case closed? Not at all.

"The ever-changing accounts gave rise to uncertainty," says Dr Kenneth Drinkwater, senior lecturer in psychology at Manchester Metropolitan University, who specialises in the anomalous and paranormal. "The first message that went out was unclear. Then they changed the message, and it led to suspicion that something was going on and being covered up. It gives rise to a feeling that something is being hidden from the general population, leading to speculation of possible conspiracy and possibly alien technology."

It's why the Roswell files remain open in the eyes of many, and investigators put great value on the testimonies of those who were there, many of them respected military. "Every member of Blanchard's senior staff, with a single exception, suggested the craft was of alien origin," says ufologist Kevin D. Randle, a retired Lieutenant Colonel of the US Army Reserve who served in Vietnam and Iraq. "Major Edwin Easley, the base provost marshal, told me, when asked if we were following the right path – meaning extraterrestrial – that it wasn't the wrong path."

The 'single exception' is Cavitt, the retired Lieutenant Colonel of the US Air Force who accompanied Marcel to the debris site. His careful testimony suggested nothing untoward happened. He said he had never been threatened by anyone in government and that the debris wasn't extensively scattered. Yet UFO investigators say that if the wreckage was Project Mogul, then this testimony doesn't ring true. Mogul arrays were so big, the debris field would have been large.

"Everyone agrees that something fell at Roswell, but there is no terrestrial explanation," Randle tells **All About Space**. "Project Mogul fails because the documentation tells us that flight number four – the alleged culprit – was cancelled. It did not fly. All other explanations have failed too: it wasn't an aircraft accident, not a rocket from White Sands and not a regular weather balloon."



Roswell Daily Record

Claims Army Is Stacking Courts Martial

RAAF Captures Flying Saucer On Ranch in Roswell Region

House Passes Tax Slash by Large Margin

Security Council Paves Way to Talks On Arms Reductions

No Details of Flying Disk Are Revealed

Ex-King Carol Weds Mme. Lupescu

Soviet Satellites End Paris Meeting

American League Wins All-Star Game

Miners and Operators Sign Highest Wage Pact in History

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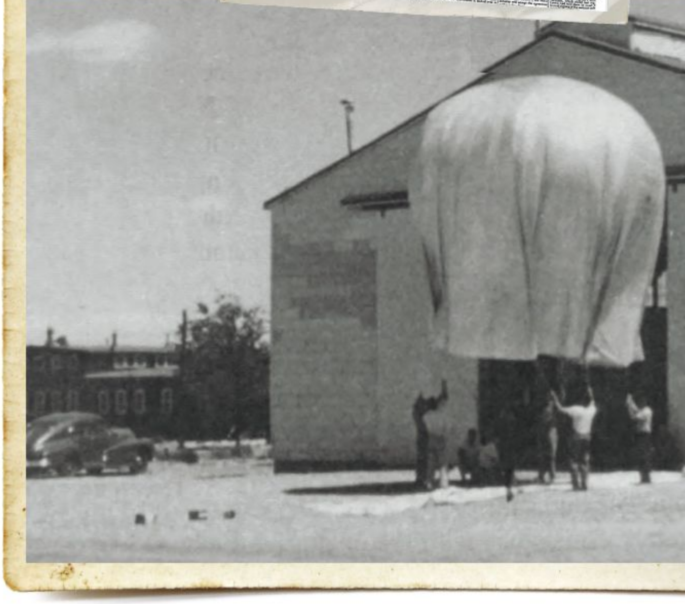
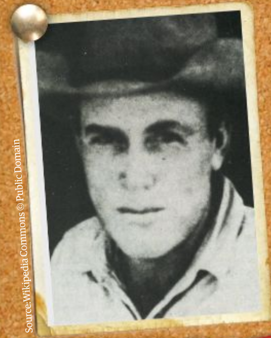


Top right: The *Roswell Daily Record* reported on the RAAF's capture of a flying saucer, a story based on the initial press release

Right: Huge balloons developed by Seyfang Laboratories were used during Project Mogul, according to a US government report issued in 1994. Their metallic exterior coating meant they were often mistaken for flying saucers

© US Gov

KEY PEOPLE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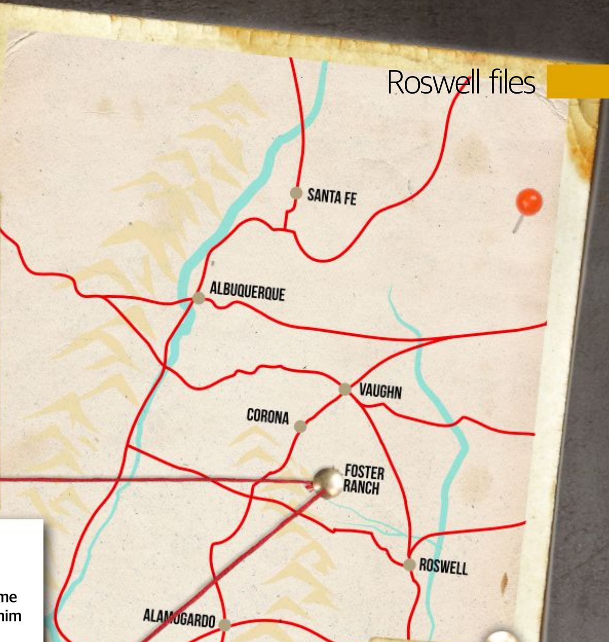


William Brazel

Owner of a ranch near Corona, New Mexico

Brazel discovered the scattered debris and reported it to the authorities, believing it to be evidence of a flying disc.

George Wilcox

Sheriff of Roswell

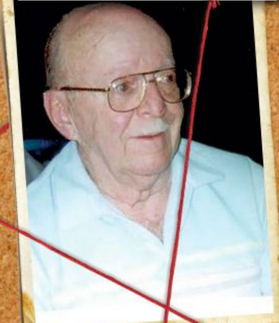
Wilcox met with Brazel and saw some of the gathered debris, prompting him to call upon the military.

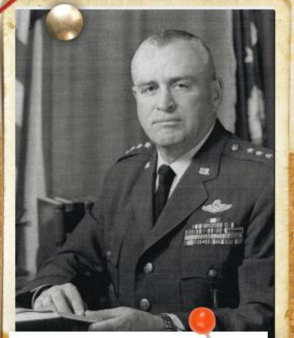
Source:Wikipedia Commons © Public Domain

Sheridan Cavitt

Head of counterintelligence

Accompanied Marcel on the site visit on 8 July 1947, saying what was found was consistent with a balloon having crashed.

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Walter Haut

Public information officer of the 509th Bomb Group

Drafted a press release which announced the US Army Air Forces had recovered a 'flying disc'. He would later say he saw alien corpses.

Jesse Marcel

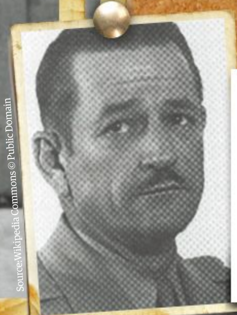
Intelligence officer of the 509th Bomb Group

Marcel was sent to view the crash site. He collected debris, becoming convinced that it was from another planet.

William Blanchard

Commanding officer of the Roswell Army Air Field

Wilcox contacted Blanchard at the RAAF, who sent agents to examine the site. He ordered the original press release that started a media frenzy.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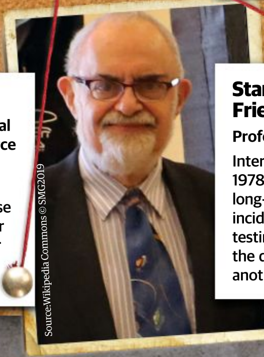
Roger Ramey

Commanding General of the Eighth Air Force

Headed a press conference the day after the press release suggesting a weather balloon crashed near Roswell, and not a UFO.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Stanton T. Friedman

Professional ufologist

Interviewed Marcel in 1978 and revived the long-forgotten Roswell incident by revealing testimony that claimed the debris was from another planet.

Source:Wikipedia Commons © Public Domain

Steven Schiff

American politician

Representative Schiff requested a report into the Roswell incident, published in 1994. It claimed what crashed was a top-secret Project Mogul balloon.

IS THE TRUTH REALLY OUT THERE?

© Ben Smith

Former CIA operative Ben Smith investigated the crash which took place in Roswell in 1947 for a television documentary aired on the History Channel, or Sky History in the UK, called *Roswell: The First Witness.* He spoke to the grandchildren of Major Jesse Marcel, the person sent to the crash site to gather debris for analysis. He also visited the site with aviation crash experts, studied a journal found among Marcel's possessions for clues and spoke to other witnesses. Was Marcel right? Was the evidence gathered that day really not of this Earth?

Before you began investigating, were you sceptical about what happened that day in 1947?
I think my initial attitude was one of not scepticism, but healthy doubt. Being a member of government, having formerly worked for the CIA, I'd seen how information is compartmented. The priorities, from a national security standpoint, didn't really seem to align with aliens and the possibility of a huge, vast conspiracy. I've been involved with some pretty expensive operations and I had never heard about the need to cover something like this up. But maybe I was so low or unimportant that I didn't know everything that was going on at the CIA.

In the series you heard Marcel's version of events, not only through his family, but via tape and video recordings from past interviews. Do you believe what he was saying was true?
Listening to the recordings, talking to body language experts, getting to know Marcel's family and seeing the fruits of his personality and his character manifested in his children and his grandchildren, I did believe his account in so much that he believed it, and I don't think he was lying. But I still found discrepancies.

We had Jesse saying that what he found was like balsa wood, but his son calling it an i-beam, so there are already witnesses with different accounts. And then you stack on properties of what was found, like 'memory metal' and 'unbreakable', and I could not find any direct evidence that these claims were from Jesse Marcel's mouth. That was always a tricky part. What came first: the idea of memory metal or the witness accounts?

How trustworthy are personal accounts?
Personal accounts are always tricky, even in the intelligence world, especially when you have individuals claiming they have access to super-important information about enemy plans or a terrorist attack or what have you. You always have to take that with a grain of salt. You always have to investigate the person's motivations, their mental stability, because the last thing you want to do is sell fiction, or something not true, that could result in something terrible, like a war, based on false information. There's a tricky aspect to this, and that's part of the challenge of dealing with something 70 years old. I really tried to do my best to cut through and focus on hard evidence and then weigh people's accounts with what we could find.

There was a lot of focus in the documentary on a journal found among Marcel's possessions. Why was it seen as a vital piece of evidence?
There are two factors: one, the words were written in an Army handbook around the same time of Roswell, and two, it was among the very few documents Marcel passed to his children. He handed over his military records, his medals and this journal to his son, and then later his grandchildren. I think as a primary document or a firsthand account, it's really the first potential evidence we have of what really happened at Roswell outside of some of the oral histories, and the question is why was this diary so important to him. Reading it, it seems to be a series of random musings, so we wanted to see if there was a code in there. As we saw in the series, codebreaking didn't work out. But there's still a possibility that the person who wrote it – and we found it wasn't Marcel himself – would remember, if they're still alive. I hope I get the chance to keep following up on it.

The government says the object that crashed was a high-altitude balloon used as part of a mission to spy on Russian atomic tests called Project Mogul. Did your investigation reach the same conclusion?
That was the confusing part. We took a safety aviation crash expert to the site, and he at first ruled out the idea of a Mogul balloon, said it was just impossible for it to have been a balloon. We had another witness scheduled who has pretty convincing research that suggested it definitely wasn't a balloon. I'm not convinced by the excuse.

Were there any people that you wanted to speak to as part of the investigation?
We had more witnesses lined up, but we kind of got hit with the pandemic and travel and health and safety issues, so we didn't get to do all that we wanted to. I would love to have interviewed some of the original researchers like Stan Friedman, who was one of the first to propose the theory that this was a government cover-up. I would have liked to ask the hard questions about who was the first person to say 'memory metal'. Who used that? Where did it come from? I was able to get time with folks like researcher Don Schmidt, who interviewed a lot of the original witnesses, but even he couldn't give those kinds of answers.

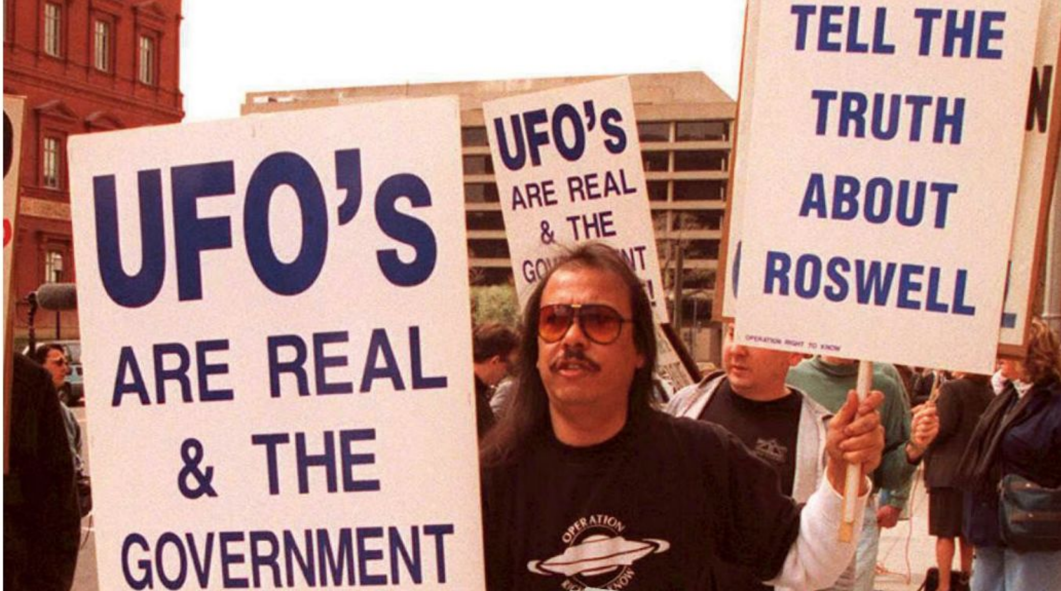
So you'd like to continue the investigation?
Oh, absolutely. I don't think I'm done, and it's definitely made me more curious. I think there were a number of leads that we generated that I want to follow up on, and it's still an open question in my mind. Until I feel like I have enough to form at least not a foolproof opinion, but something I could tell viewers that I think happened, then I won't be satisfied. My investigation so far hasn't convinced me either way, and I need hard evidence, but I think we got closer than others in looking for a conclusion.

© History Channel

Left: Jennifer Naso forensically examines an intriguing journal found in Marcel's possessions to see if it dated to 1947 and could potentially hold clues

Right: Protestors march in front of the General Accounting Office in the mid-1990s, convinced of a government cover-up over what happened

Right below: The documentary recreated the moment William Brazel and his seven-year-old neighbour Dee Proctor found the wreckage


UFO'S ARE REAL & THE GOVERNMENT KNOWS IT!
OPERATION RIGHT TO KNOW
UFO'S ARE REAL & THE GOVERNMENT KNOWS IT!
TELL THE TRUTH ABOUT ROSWELL
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© Roswell: The First Witness

"EVERYONE AGREES THAT SOMETHING FELL AT ROSWELL, BUT THERE IS NO TERRESTRIAL EXPLANATION" KEVIN D. RANDLE

Over the past 40 or so years there have been new claims and fresh leads, not only adding to the mystery, but keeping the Roswell files very much alive. UFO investigator Calvin Parker, for example, recently spoke of his time with Marcel, who before he died in 1986 revealed he'd hidden three pieces of metal from the crash site in the top of his water heater in his house. They have never been recovered, however.

Investigators are also keen to stress that they don't take every testimony at face value. Randle has said in the past that the credibility of Dennis must be discounted because of inconsistencies, and he tells us that the accounts of military personnel are not simply accepted just because of their background. "There are some military witnesses who have been discredited as inserting themselves into the tale," Randle says. Likewise, there are civilian witnesses which are compelling.

"There are some very creditable civilian witnesses, such as Brazel and Frankie Rowe," Randle continues. Rowe is certainly an interesting case. She was told of the crash by her father, a firefighter, who described creatures he had seen. Rowe said she was shown debris from the crash site, but had been told to stay quiet by the state. She says there was evidence her phone had been tapped. But of all of the witnesses, is too much weight being put on Marcel's account?

"If Marcel was standalone then there would be some real problems here, but he is not. There are many credible witnesses – men who achieved high military rank, men and women who were prominent in their communities – who believe the craft was alien," Randle explains.

"We have attempted to eliminate the fakers from those who had information to provide. We have been taken in, for a time, by some of those fakers, but in the long run it was we who investigated the case that removed many of those fakers, though based on evidence and not a belief there is no alien visitation. The point is that Marcel was backed up by other high-ranking officers, and many civilians who were part of the case. Marcel told what he had seen and done, and there was little embellishment in his testimony."

Randle appeared in a recent documentary called *Roswell: The First Witness*. It followed the investigations of former CIA operative Ben Smith into Roswell, and a key part of the series was a journal found in Marcel's possessions that was initially thought to have been written by him.

It turned out that the journal – which consisted of quotes, lyrics and jokes – could be dated to the time of the Roswell incident, but the handwriting didn't match Marcel's. Smith pondered why the former army officer retained the journal, and there was speculation over whether it may have contained a code. If it did, however, it could not be deciphered by even the best of minds.

Smith also sought to discover what was written in a document held by Brigadier General Roger Ramey, Eighth Air Force commander, during the press conference. It was captured in a photograph taken by *Star-Telegram* reporter J. Bond Johnson, and ufologists have long wondered whether the words they struggle to make out refer to 'victims of the wreck'. As Smith found, however, even the best technology could not sufficiently clean the document to make the words readable, and they remain a source of debate.

There were other interesting explorations in the documentary series. A body language expert examined video interviews of Marcel and said it appeared he was telling the truth, at least as he saw it. Experts including aviation crash investigator David Soucie were also taken to examine the crash

WHAT WAS THE OBJECT?

A flying saucer

Some would label the proponents of this argument as UFO conspiracists, but research based on the accounts of military personnel and apparent witnesses to the Roswell event ensures this theory won't go away and is now seared into the public consciousness.

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Weather balloon

The remains of a weather balloon was the explanation given the day after the US Army sought to quickly play down a press release claiming a UFO had been found. Authorities have since admitted this claim was false.

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Project Mogul

In 1994, the National Security Agency published a report which connected Roswell to Project Mogul, a top-secret Army project that launched high-altitude balloons into the ionosphere above the desert. They were built to monitor Russian nuclear tests.

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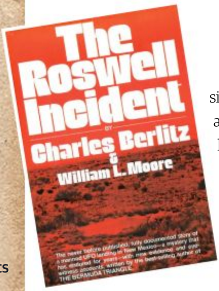

Above: The first conspiracy book about Roswell was *The Roswell Incident*, written by Charles Berlitz and William Moore in 1980

Below: Roswell relishes its role as the ufologist capital of the world, with even McDonald's taking a bite of the ongoing interest

site. Interestingly, the wind currents in the area were found to be inconsistent with a lightweight balloon crashing in the way that was described.

As the documentary continued, more evidence emerged. Crucially, there was a taped interview conversation between Marcel and author Linda G. Corley in which the military man discussed the items he found in 1947. "I found all this stuff and I was told to keep my mouth shut," he told her. "I held on to this premium for 32 years without saying anything at all. See, I was an intelligence officer. I handled intelligence and security for the base. I still hold an allegiance to my country, the vow that I took to keep my mouth shut about everything that might encroach on military secrets."

Just as compelling was an account from the family of Patrick Saunders, the 509th adjutant who is likely to have known about the whole event. He had apparently told people that it wasn't a weather balloon, but something similar to a jet fighter, that files were destroyed or changed and that the world wasn't ready for the truth because it would cause social upheaval. Were the 'beings' friendly, he was said to have pondered.

This kind of testimony – particularly the first-hand testimony of Marcel that was chronicled in Corley's book, *For the Sake of My Country* – ensures the incident remains open. The fact the US government admitted there was a cover-up in 1994 only continues to add fuel to the fire.

Yet Drinkwater says failure to provide physical evidence means anecdotal accounts have spread misinformation, and he remains in doubt. "Colonel John B. Alexander offers an excellent insight into the myths and possible conspiracies connected to UFOs, the Roswell incident, the government involvement and so on," he says. "I think it's more about a sense of reality and how it can be swayed emotionally. I'm dubious about the nature of a secret operation where many might not have known about the goings on at their level."

So what of those who likely know: presidents past and present, perhaps? Former president Donald Trump told his son Don Jr. in an interview on YouTube in June 2020 that he'd heard some "interesting things" about aliens, thereby ensuring speculation will continue for some while yet.

"Would you ever open up Roswell and let us know what's really going on," Don Jr. asked, to which Trump responded: "There are millions and millions of people who want to go there and want to see it. I won't talk to you about what I know about it, but it's very interesting."

That's something countless people will no doubt chew over if they happen to visit and find themselves in that extraordinary McDonald's. Roswell is a town that will be forever linked to one of the greatest mysteries of all time, and we may never truly reach a consensus on the truth that is out there.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

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INSTANT LANDING PAD

Touching down on a new planet can be unsettling, but Masten Space Systems aims to put things on a firmer footing

At the start of Apollo there was huge concern and uncertainty about what kind of surface awaited. While some expected barren rock, others suggested a lunar lander might sink deeply into Moon dust. NASA sent the Surveyor probes ahead in the 1960s to characterise the surface, determining, as seen in the famous lunar landing footage, that it was somewhere between the two.

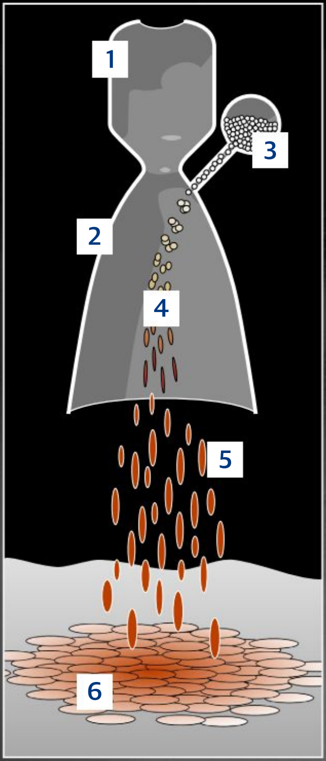
Moon dust was found to be a problem: it is fine and abrasive, a harsh glass mix that brought a burnt smell with it back into the Lunar Module. Now NASA is actively working on Project Artemis, and is closer to returning to the Moon than at any time since the end of Apollo. Along with SpaceX and Blue Origin's commercial ventures and China's plans for future lunar landings, we are at last likely to see the start of a moonbase in the next decade.

Such a base will need ongoing launches and landings. Longer term hard concrete landing pads will likely be cast from Moon dust, but there will be a pioneer phase when multiple craft could be scouring away dust and blasting it around the base. Large Artemis mission landers may even launch dust into lunar orbit with their rocket exhaust. The ideal situation would be for landers to bring their own pad with them, and US aerospace company Masten Space Systems is working on a concept to do just that.

Masten Space Systems was founded in 2004 and has become well known in the aerospace industry, if not to the broader public, for innovative rocket-powered landing test vehicles. In 2009 it won the $1 million (£730,000) prize at the Lunar Lander Challenge X Prize with its Xoie lander, and participated in DARPA's XS-1 project to develop a rapidly responsive orbital launch. More recently its Xombie lander was used by the Jet Propulsion Laboratory to develop the Lander Vision System, used to fly the Perseverance rover's skycrane as it set the rover down on Mars.

Masten has received a NASA Institute of Advanced Concepts (NIAC) grant to develop the Masten in-Flight Alumina Spray Technique (FAST) pad. In this project, Masten is studying the potential of introducing alumina, a type of aluminium oxide, into the rocket engine of a descending lander. Fired in just after the throat of the engine, the particles would partially melt, splattering over the landing site as the lander approached. As the alumina deposit cools it bonds the planetary dust together, building up a landing pad to prevent dust being blown away.

Long-standing specialists in vertical landings, Masten may be the first to put this technology into practice on the Moon with its XL-1 lander in 2022. As part of the effort to return to the Moon, NASA has established the Commercial Lunar Payload Services initiative, with a number of US aerospace companies building landers for lunar science on a commercial basis. Masten's XL-1 lander is targeted for landing at the lunar south pole no later than December 2022.



1 ROCKET ENGINE

Masten has developed a range of rocket engines, and even its own self-lighting propellant, MXP-351, for use in its lunar lander.

2 ROCKET NOZZLE

The classic diverging shape of a rocket nozzle converts the stored energy of high-pressure gas into kinetic energy in the exhaust stream, improving thrust.

3 ALUMINA PARTICLES

Alumina, or aluminium oxide, is stored as pellets and injected into the hot rocket exhaust gases just after the throat of the engine.

4 MOLTEN PELLETS

The alumina rapidly melts in the hot gas stream and is ejected from the engine towards the landing area.

5 ALUMINA SPRAY

The droplets of molten aluminium oxide spray over the landing area as the lander descends.

6 LANDING PAD

The alumina droplets join together as they cool, bonding the planetary dust before it can be blown away.

7 MASTEN XL-1

Masten's lunar lander is scheduled to arrive at the Moon no later than December 2022, carrying both NASA and commercial payloads.

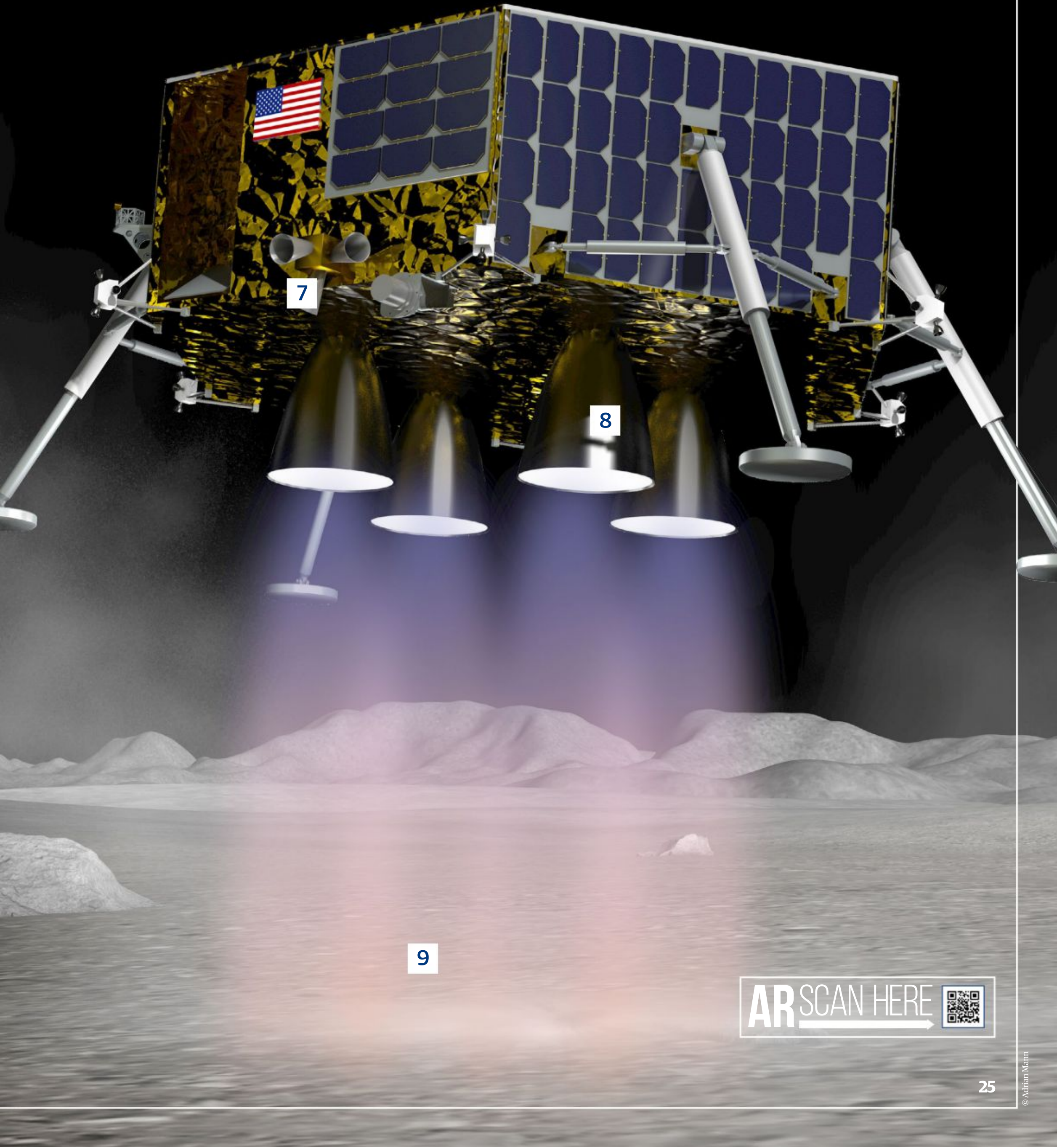
8 MASTEN ENGINES

Four of Masten's own engines will lower the XL-1 to the surface, hopefully laying a landing pad as they do so.

9 LUNAR SOUTH POLE

The lunar south pole is of great interest as it offers the potential of a lunar water supply and near constant solar power.

> “THE IDEAL SITUATION WOULD BE FOR LANDERS TO BRING THEIR OWN PAD WITH THEM”



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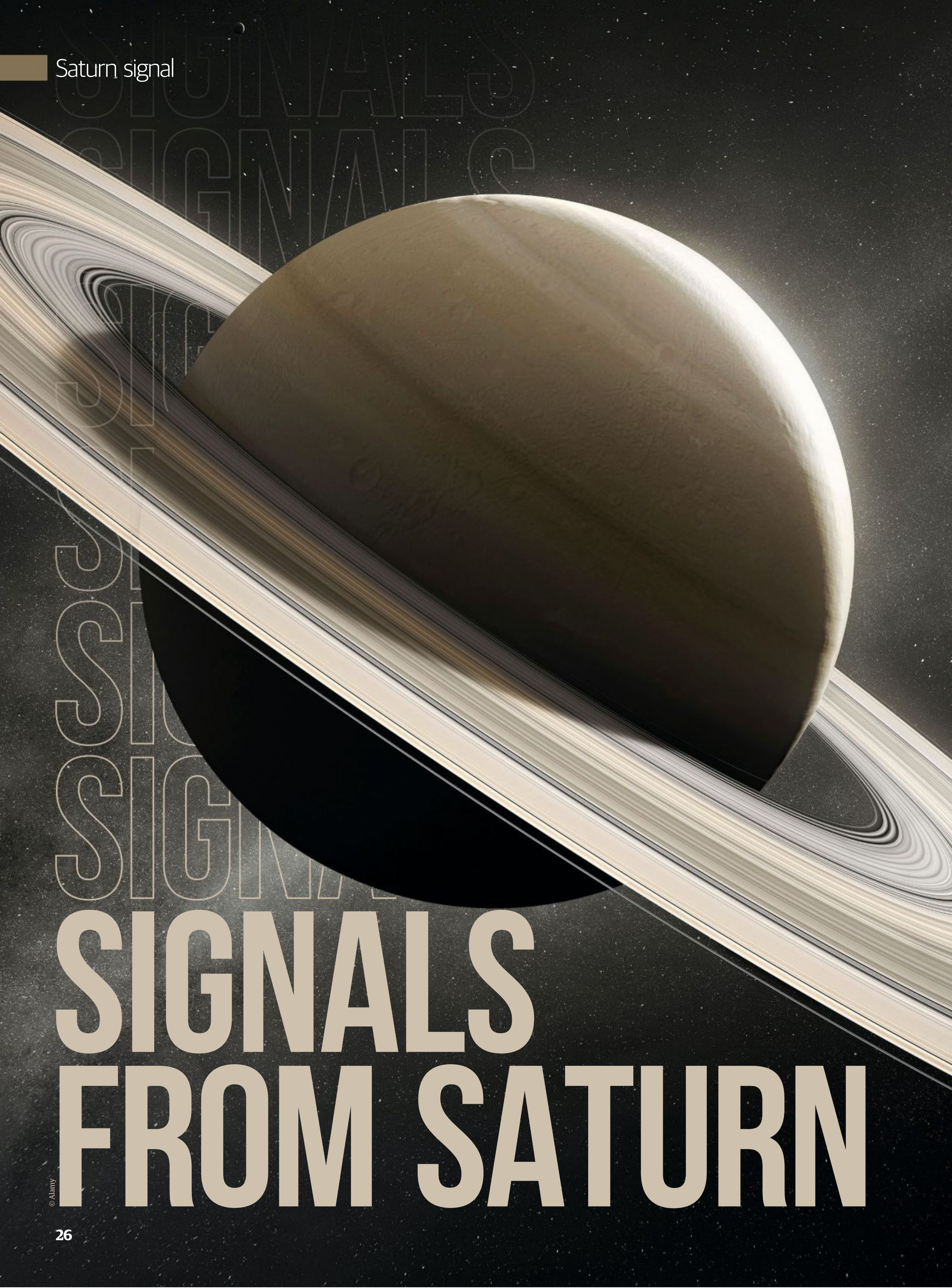


SIGNALS FROM SATURN

© Alamy

An unusual signal from the ringed planet's moon Rhea now has a possible explanation

Reported by Nigel Watson

When NASA's Cassini spacecraft flew past Rhea, Saturn's second-largest moon, it detected an unexpected and puzzling change in the ultraviolet radiation reflected from its surface. The data from Cassini's flybys has led to a range of speculation and possibilities. Dr Amanda Hendrix, an expert in ultraviolet spectroscopy of planetary surfaces at the Planetary Science Institute in California, said that they noticed a dip in the spectrum and wondered if it was caused by some type of water ice. It was certainly an intriguing puzzle.

The signal was detected by the Cassini craft that was launched from Cape Canaveral on 15 October 1997. After seven years of travel it reached Saturn on 1 July 2004, and in total it orbited the planet for over 13 years. When it became very low on fuel it was decided to end the mission, and to avoid biological contamination of the planet or its moons it was deliberately sent into Saturn's atmosphere, where it burnt up on 15 September 2017.

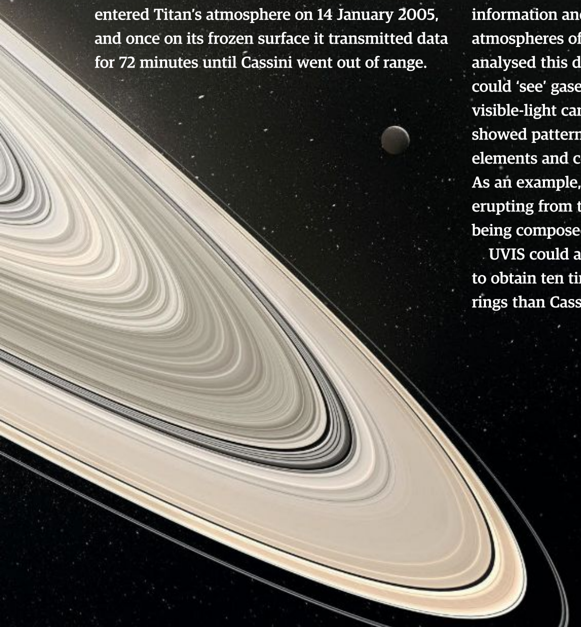
Cassini is one of the largest ever interplanetary probes to be built, weighing 2,150 kilograms. It carried the European Space Agency's (ESA) Huygens lander probe, which it sent towards Titan, Saturn's largest moon, on 25 December 2004. After 21 days of travel Huygens finally entered Titan's atmosphere on 14 January 2005, and once on its frozen surface it transmitted data for 72 minutes until Cassini went out of range.

Since then scientists have researched this information to investigate the atmosphere of Titan and its geology. They made several important discoveries, including the fact that the levels of methane increased as the craft descended, whereas the amount of nitrogen remained constant. The presence of methane is exciting because it could be produced by micro-organic life, but ESA scientists think it is more likely large amounts of liquid methane are trapped under the surface ice and released into the atmosphere by cryovolcanism.

Besides the ill-fated Huygens, Cassini carried a large array of instruments to study Saturn and its moons. Some of these measured its magnetosphere and the presence of dust particles, and infrared, visible and ultraviolet images were captured using cameras and spectrographs. It was the Ultraviolet Imaging Spectrograph (UVIS) science package that detected the puzzling findings sent back from Rhea. The UVIS included a two-channel system for studying far and extreme ultraviolet light in wavelengths of 55.8 to 190 nanometres (nm).

The light reflected from planetary objects passed through the four UVIS telescopes into a spectrograph, where it was split into its component wavelengths. These wavelengths, invisible to the human eye, were able to show information and images of the night side atmospheres of Saturn and Titan. Hendrix, who analysed this data, said that this ability meant it could 'see' gases that were not seen by Cassini's visible-light cameras. This ultraviolet light also showed patterns that revealed the chemical elements and compounds in the Saturn system. As an example, it identified a plume of material erupting from the south pole of Enceladus as being composed of water.

UVIS could also use an occultation technique to obtain ten times more detail of Saturn's rings than Cassini's visible-light cameras. This



RHEA
BY NUMBERS

1672
Year Giovanni Cassini discovered Rhea

1847
Year it was named by John Herschel

1,528 KM
Diameter of Rhea

-174°C
Maximum surface temperature

-220°C
Minimum surface temperature

1.233
times denser than liquid water

4.518
Days it takes to orbit Saturn

527,068KM
Average distance from Saturn

THE WONDERS OF SATURN
AR SCAN HERE

SATURN'S FAMILY PORTRAIT

The sixth planet from the Sun has a distinctive ring system and at least 82 moons

1 Titan

The giant of the Saturn family, it is bigger than our own Moon and a little bigger than the planet Mercury, having a diameter of 5,149.46 kilometres (3,200 miles). It takes roughly 16 days to orbit Saturn and permanently presents one side towards the planet.

There is the exciting possibility that primitive life forms might exist in the liquid water ocean that lies beneath the moon's surface. Unlike any other moon in the Solar System it has a substantial atmosphere that is mostly composed of nitrogen and methane.

2 Rhea

The second-largest moon. The surface is mainly composed of water ice and it has an ice mantle. Its chemical composition and evolutionary history are very like that of Dione. They both have ice cliffs that are caused mainly by tectonic strains that fractured the moons' surfaces. The side of Rhea that always faces away from Saturn has two large impact craters: the 500-kilometre (311-mile) diameter Mamaldi basin and the 360-kilometre (224-mile) diameter Tirawa basin. The impact scar of Tirawa overlaps Mamaldi, indicating that it is geologically younger. The unusual far-ultraviolet radiation from Rhea detected by Cassini, centred near 184 nanometres in the electromagnetic spectrum, was probably caused by hydrazine. How or where it comes from still remains a mystery.

3 Dione

Although it's smaller than Rhea, it has a higher mass density, which is 1.48 times that of liquid water, indicating it has a silicate rock core surrounded by ice. It might even have a liquid salt water ocean beneath its surface. An outstanding feature of the moon is a bright pattern of icy cliffs that were seen as long, wispy streaks in the images from the Voyager probes.

It has a landscape of craters, tectonic fractures and a tenuous exosphere. Some of the craters are 100 kilometres (62 miles) across, and there is a variety of heavily and lightly cratered plains.

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What is hydrazine?

Hydrazine is a colourless, inorganic liquid that is highly combustible and smells like ammonia. It has similar properties to water in terms of density, surface tension, viscosity and freezing point. It is very toxic and can cause burns and serious damage to vital organs. It is often used to propel thruster motors on spacecraft. They work by hydrazine being exposed to a catalyst, causing the release of heat and gas that is directed out of the engine's nozzle.

involved UVIS locking onto a bright star and recording how the ultraviolet light changed when the rings of Saturn or a planetary body passed between them.

The perplexing dip in the far-ultraviolet from Rhea, centred near 184nm, is outlined in Dr R. Mark Elowitz' PhD thesis *Far-Ultraviolet Spectroscopy of Saturn's Moons Rhea and Dione*. In it he notes that data from Rhea and Dione showed a weak absorption feature near 184nm, and that as early as 2008 it was found that Phoebe presented similar readings. At the time, various ice mixtures of water, tholins, carbon, kerogen and poly-HCN could not explain this feature. Observations of Mimas, Enceladus and Tethys have also revealed absorption spectra in the same region of the spectrum.

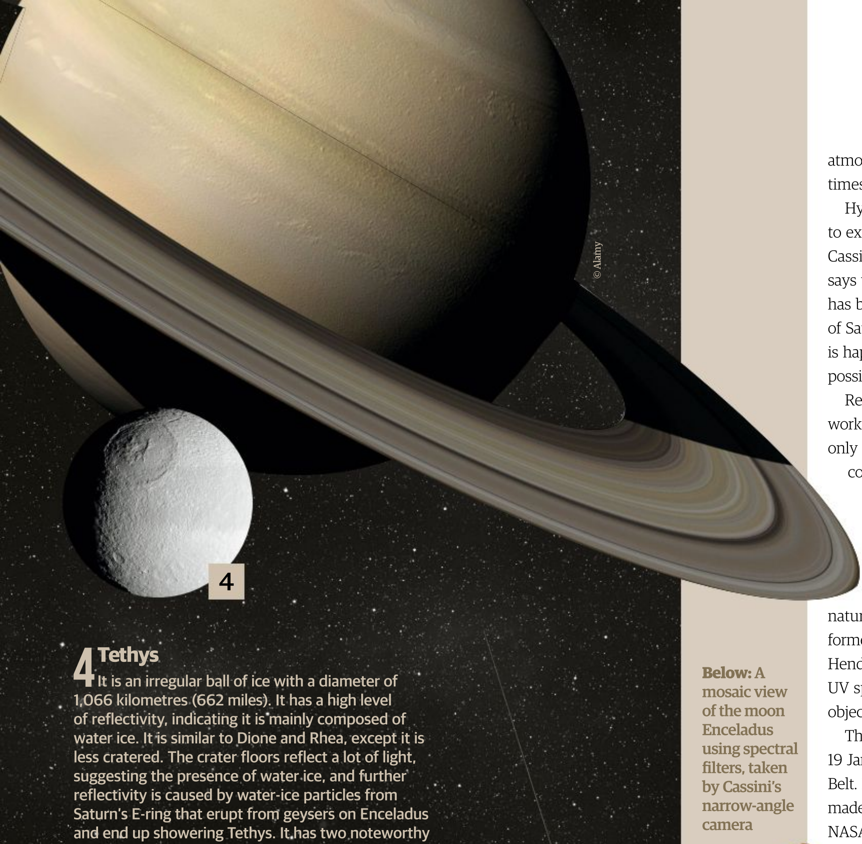
To explain the Rhea signal, scientists decided the best route to an answer was to compare the spectra collected by Cassini to the spectra of thin-ice measurements in the laboratory. The far-ultraviolet data was extracted from targeted flybys of Rhea in 2007, 2010 and 2011 using datasets that completely filled the moon's surface and provided the highest signal-to-noise spectra. Elowitz, who was one of the team members, says: "Over 20 modelled spectra of different chemical species of interest to studies of icy moons in the outer Solar System were compared with the Cassini observational data, with only two chemical species representing a good fit to the observed reflectance spectra. Those two chemical species included simple chloromethane molecules and hydrazine monohydrate. To determine the most likely of these two chemical species to exist in the upper surface ice layer on Rhea, the different sources and sinks of each chemical compound were explored, including the various chemical pathways that could lead to their production."

Considering the two possible chemical compounds, it was determined that simple chloromethane compounds are least likely to be the answer. As Elowitz notes: "It would require the presence of a deep subsurface ocean under the ice shell of Rhea. It is unlikely the chloromethane compounds or salt derivatives of these compounds could migrate upwards through tiny cracks or fissures over hundreds of kilometres to the surface."

The only other possible source of chlorine is via exogenic delivery by chondritic asteroids or micrometeoroids throughout the history of Rhea. If these simple chloromethane compounds were scattered over Rhea in this manner, they would produce by-products on the surface ice of Rhea. These chemical by-products were not found, so this possibility had to be ruled out.

That left the researchers having to explain why hydrazine monohydrate was detected. One immediate possibility was that the Cassini craft itself produced the hydrazine, as it was equipped with a 132-kilogram tank of hydrazine that fuelled its 16 attitude and small trajectory thruster motors.

Professor Nigel Mason, head of the School of Physical Sciences at the University of Kent and a co-author, along with Elowitz and Hendrix, of the science paper *Possible Detection of Hydrazine on Saturn's Moon Rhea*, says: "We looked at spectra of other moons, like Dione and Tethys, since if the



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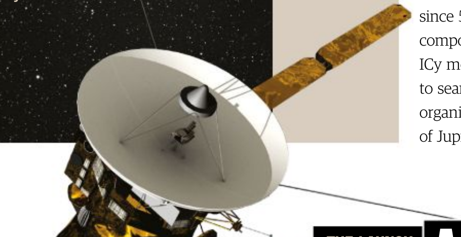
4 Tethys

It is an irregular ball of ice with a diameter of 1,066 kilometres (662 miles). It has a high level of reflectivity, indicating it is mainly composed of water ice. It is similar to Dione and Rhea, except it is less cratered. The crater floors reflect a lot of light, suggesting the presence of water ice, and further reflectivity is caused by water-ice particles from Saturn's E-ring that erupt from geysers on Enceladus and end up showering Tethys. It has two noteworthy features: the Ithaca Chasma, a 1,930-kilometre (1,200-mile) long crack along its surface that covers 75 per cent of its circumference, and the 445-kilometre (276-mile) Odysseus crater that dominates the western hemisphere. It's possible that its impact helped create the Ithaca Chasma.



signal was present on all moons it might suggest we should look for a common source, for example spacecraft fuel contamination of the spectrometer. The data from Tethys showed no signal, and we looked at other spectra to check for contamination and if the spacecraft motors were firing during or before observation to leave a 'plume' of hydrazine."

The spacecraft's own thrusters seemed a very likely culprit, but they had to be ruled out because they were never fired while Cassini made its flybys of Rhea. And, as Mason points out, hydrazine fuel would have contaminated data gained from other moons and not just showed up when it looked at Rhea.

Elowitz explains that if there is ammonia on the icy surface of Rhea, it could produce hydrazine "by irradiation from high-energy particles originating from Saturn's magnetosphere". However, he continues: "An alternative explanation is that hydrazine is produced on Titan from irradiation of ammonia present on its surface and/or atmosphere. The hydrazine then escapes from Titan's atmosphere and is deposited over geologically long timescales on Rhea's upper ice layer."

Hydrazine therefore remains the prime candidate to explain the absorption signature seen in the Cassini far-ultraviolet spectral data, though Hendrix says we still need to figure out why this feature has been observed on some of the other moons of Saturn. In her view it indicates that this process is happening throughout the Saturn system, and possibly elsewhere.

Regarding future studies, Mason says: "In future work we are looking at spectra of other moons, not only to search for hydrazine, but to look for other compounds. The UV spectral database is used to look at other planets and moons, so we are exploring the chemistry of Jovian moons in preparation for the JUICE mission, and hopefully data from the Juno mission now it has been extended. Due to their volcanic nature, sulphur compounds are expected to be formed on those moons, so we are looking for these. Hendrix is also on the New Horizons team with the UV spectrometer, so data from Pluto and Kuiper Belt objects is being analysed as well."

The New Horizons space probe was launched on 19 January 2006 to explore Pluto and the Kuiper Belt. It swung past Jupiter in February 2007 and made its closest approach to Pluto on 14 July 2015. NASA's Juno space probe has been orbiting Jupiter since 5 July 2016, where it has been studying the composition of the planet. The ESA's JUICE (JUpiter ICy moons Explorer) is scheduled for launch in 2022 to search for possible habitable environments for organic molecules in the icy crusts and ocean layers of Jupiter's moons Ganymede, Callisto and Europa.

Below: A mosaic view of the moon Enceladus using spectral filters, taken by Cassini's narrow-angle camera

THE LAUNCH OF CASSINI

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Above: Technicians were dwarfed by the huge Cassini-Huygens craft as they tested it in 1996

The data from these missions might well help us further with the study of Saturn's system and the mysterious presence of hydrazine.

To investigate the matter further, Elowitz, in his PhD thesis, proposes that future space probes should be equipped with infrared and ultraviolet spectrometers to examine the surface of Rhea and the similar icy moons of Saturn. Cassini's UVIS instrument could be improved by employing a hyperspectral imaging system. Each pixel in the multi-layered sensor would obtain spatial and spectral information. The far-ultraviolet spectrum data received by each pixel would identify chemical compounds by reference to their reflective properties, and the whole instrument would be able to create detailed geochemical maps of selected areas of interest. "The detailed spectral maps would be used to characterise the spatial variability of the abundance of hydrazine monohydrate or chloromethane molecules, which could not be performed using the previous Cassini UVIS data due to limitations resulting from low signal-to-noise," notes Elowitz.

The use of advanced spectrometers with higher sensitivities could be used to examine the upper layers of Rhea, Dione and Tethys for the presence of hydrazine monohydrate or chlorine molecules, and it would be great to send landing craft to these moons. The Curiosity rover carried mass spectrometers and gas chromatographs that detected dichloromethane on Mars, so any future surface landers on the icy moons should be equipped with similar equipment to help verify the existence of hydrazine or chloromethane. Certainly there is plenty more to learn and understand about this fascinating signal.

Nigel Watson
Space science writer
Nigel has written extensively about science and technology, in particular about extraterrestrial contact. He is the author of four books on alien life.

CASSINI SPACECRAFT

1 High-gain antenna

The four-metre (13-foot) wide antenna sent data back to Earth, and variations in the signal helped to study Saturn's atmosphere. The central low-gain antenna had a wider, less powerful range.

2 Magnetometer (MAG)

Two magnetometers were mounted on a boom to detect the strength and distribution of Saturn's magnetic field and its influence on its moons.

3 Radio and Plasma Wave Science (RPWS)

Three ten-metre (33-foot) long antennae were used to detect radio waves and plasma in Saturn's magnetosphere.

4 Remote-sensing pallet

Included wide-angle and narrow-angle cameras along with instruments to study Saturn's electromagnetic spectrum.

5 Engines

One main engine and an unused back-up engine were used for velocity and trajectory changes. 16 thrusters were used for smaller manoeuvres.

6 Radioisotope thermoelectric generators (RTGs)

Through the decay of plutonium-238, the three RTGs supplied electrical power to the spacecraft and its instruments.

7 Huygens Titan probe

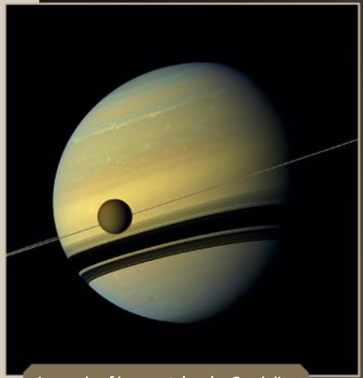
The 318-kilogram craft carried six scientific instruments to the surface of Titan, where it transmitted data back to the orbiting Cassini craft.

8 Fields and Particles pallet

Featured instruments to study cosmic dust, magnetic fields, plasma and gaseous components surrounding Saturn.

9 Radar bay

Using a multi-beam sensor, this was designed to map the surface of Titan and other moons of Saturn and study Saturn's rings.



A mosaic of images taken by Cassini's wide-angle camera – using red, green and blue spectral filters – showing Saturn, its rings and Titan.

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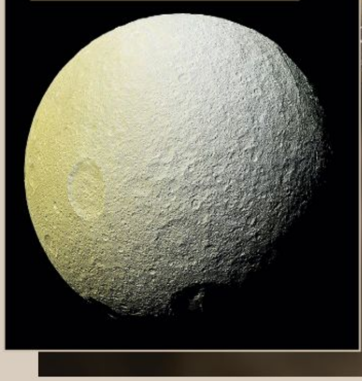

A combination of infrared, green and ultraviolet filters were used to show the subtle colour differences over the heavily cratered surface of Tethys.

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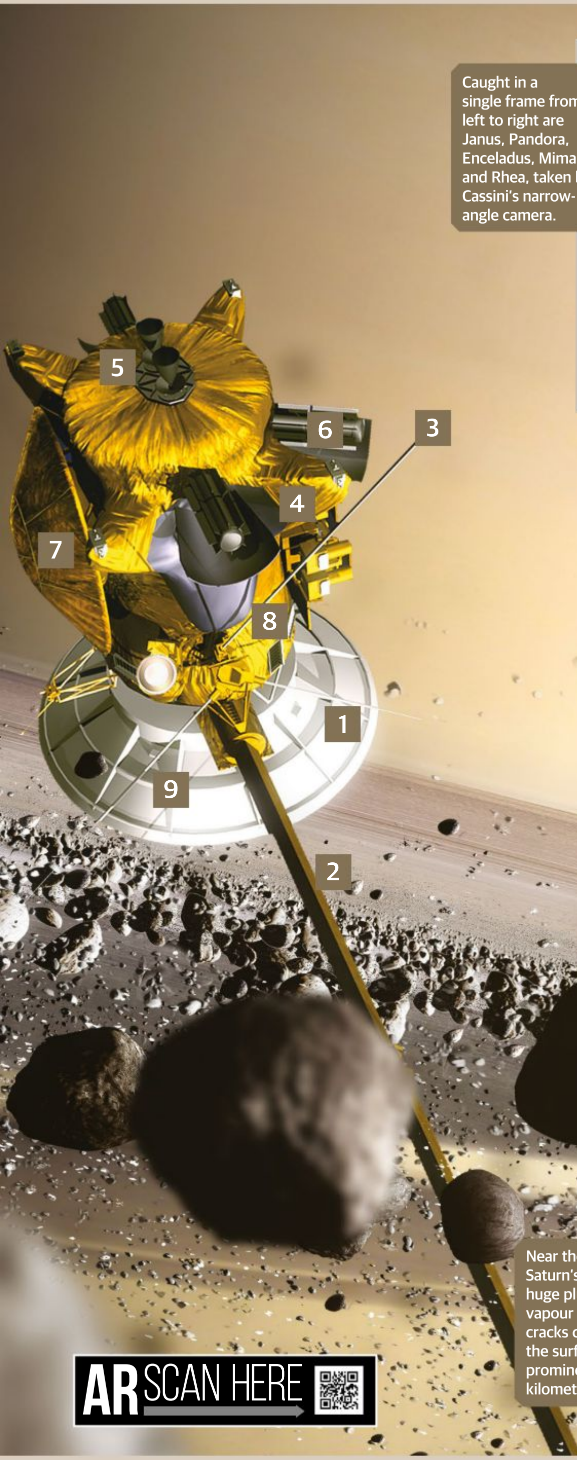

Caught in a single frame from left to right are Janus, Pandora, Enceladus, Mimas and Rhea, taken by Cassini's narrow-angle camera.

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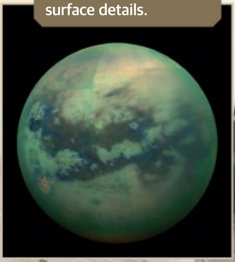
This is a composite infrared view of Titan, taken at a distance of 10,000 kilometres (6,200 miles), that penetrates the hazy atmosphere to reveal surface details.



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Near the south pole of Saturn's moon Enceladus, huge plumes spray water vapour and ice grains from cracks called tiger stripes on the surface. There are four prominent stripes, each 135 kilometres (84 miles) long.

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INTERVIEW

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BIO

Dr Queenie Hoi Shan Chan

Chan is a planetary scientist whose research focuses on investigating early chemical reactions involving liquid water in the Solar System and how the complex molecules that ultimately led to life formed. Chan's work enables her to analyse some of the most pristine samples of comets and asteroids returned by space missions such as JAXA's Hayabusa.

DR QUEENIE HOI SHAN CHAN

SEEKING THE ORIGINS OF LIFE

A planetary scientist with a very steady hand, Queenie Chan speaks to **All About Space** about her work on tiny specks of asteroid samples collected by the Hayabusa mission

Interviewed by Daisy Dobrijevic

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Why do we have to look at asteroids in space rather than breaking open a meteorite on Earth?
We have already learned so much from meteorite analysis. Meteorites bombard us every day, and we've collected thousands of meteorites on Earth. People spend time studying meteorites in every single detail in laboratories, and they're available in a much larger amount - not just tiny specks, but large rocks of meteorites - so you've got a lot more material to study. If you want to look at things like water and organics, it's better to have a lot more organic material to study, because they don't really come in large amounts, so you usually need to concentrate on them to be able to study them.

We have learnt so much about organics and water from meteorite studies in the past, but there is one problem, because all meteorites are recovered on Earth. Some are recovered as what we call a 'find meteorite', so we have found them on an exploration to Antarctica, for example, and you don't know how long they've been residing in the ice. Most of our samples are recovered from expeditions from Antarctica, but as they've been sitting in the ice water for a long time, you don't know how much terrestrial contamination they have been exposed to. It's essential that we know what is contamination and what is not, and it's a challenge to do that.

Some meteorites are recovered as 'fall meteorites', so people see when and where they fell and go and collect them as soon as they can. But even in these scenarios the meteorites are still contaminated.

This sample that we studied from Itokawa was collected by the first Hayabusa mission. It was a mission dedicated to go to an asteroid and bring the sample back for analysis. In terms of contamination, this is a much cleaner sample. This is especially important because we were going to look at water and organics, which are abundant on Earth, and we don't want contamination, which is key. We also know where the sample has come from; we know that it's an asteroid that has been sitting in its orbit around the Sun and what the orbit looks like. We have got a lot more context about the origin of the sample, rather than just a rock that we know is from outer space and has fallen to Earth.

What makes Itokawa so interesting?
It's one of what they call the near-Earth asteroids, so it comes really close to Earth during its orbit. To conduct the sampling, people calculate the shortest distance to go to the asteroid and the easiest way to then bring the samples back to Earth by the calculated orbits of both Earth and Itokawa. Another reason why we went to Itokawa is because it is an S-type asteroid. It is stony and silica rich, and it's the material of one of the most common types of meteorite found on Earth. It's called an ordinary chondrite because there are a lot of them, but we know that they're not ordinary in many other senses, as they tell us a lot about the history of the Solar System. As they are a common type of meteorite found on Earth, you would expect that they contributed a lot of material to Earth, so this is why it's interesting.

During the orbit of the Hayabusa spacecraft, it took a few images and some measurements and found something very interesting. This asteroid is supposed to be an S-type asteroid, so a stony type - it is not supposed to be rich in carbon. But on the surface of the asteroid, Hayabusa observed a large boulder about six metres [20 feet] across which was really dark in colour and looked like carbon-rich material. It's very interesting to think that the stony meteorite has got some carbon-rich material that should really be coming from C-type asteroids.

Do you think it's possible that Itokawa could have collided with a C-type asteroid?
Yes, it's possible. One thing that we know is that Itokawa is now very small. It's an elongated asteroid

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Above: 25143 Itokawa as seen by the Hayabusa spacecraft

Left: A tiny glass needle was used to pick up the miniscule fragment for analysis

> “EVERYTHING WAS VERY RISKY, AND YOU HAVE TO BE DOING THINGS REALLY SLOWLY WITH 100 PER CENT FOCUS”

about 300 by 500 metres [984 by 1,640 feet]. When we study the samples returned from Itokawa, we know that it's been heated in the past, and the reason for the heating is that the asteroid was a much larger body, at least 40 kilometres [131 miles] in diameter. Itokawa must have been impacted and shattered into pieces in the past. People have been speculating the different possible reasons for that impact, and one of them is that Itokawa collided with a carbon-rich body which caused Itokawa to fracture into pieces. But we still don't know for sure.

What difficulties did you face with analysing the sample from Itokawa?

It's extremely stressful, as the sample is so small. Before we analyse the sample we have to find it. The sample was shipped to us on a glass slide. That tiny grain of Itokawa was sitting inside a little dimple on a glass slide with a glass cover on top. When it came to transferring the sample for analysis, you had to be very careful. During the opening of the glass slide, you have some friction, and that little bit of friction could cause a bit of static electricity. The little particle could either stick on the glass slide or it could jump anywhere, so it's really challenging to even just open the main section slide. Once we opened it, we used a glass needle to pick up the sample, the same way JAXA transported the samples into the slide in the first place. If you put the needle close enough to the grain, just using static electricity it will either bounce away in the wrong direction or it will stick to the needle.

Everything was very risky, and you have to be doing things really slowly with 100 per cent focus - no heavy breathing and really hoping you won't sneeze when moving the sample! We then mounted the sample on indium - a soft metal - so we can gently press the sample in so it's fixed on the surface. Once it's fixed, then we're like: 'Okay, it's okay!' Also, this sample is from the first round of distribution to scientists around the world and is unique. My colleague Monica Grady was the one who received the particle, as she had written a proposal to get the particle from JAXA allocated to her. She then asked me to help analyse the grain. At that time we had just one grain to study... if we'd have lost it, it would have been horrible.

We used Raman spectroscopy to analyse the sample, and also another instrument called NanoSIMS (Nanoscale secondary ion mass spectrometry) for nanoscale analysis. We used very sensitive analysis techniques to study the sample in detail. Also, because we were doing water and organic analysis you would have to constantly think of ways to prevent contamination caused by yourself in the lab.

How did JAXA decide who would get a piece?

We had to write a full proposal to tell them what we are going to do with a sample. We had to say whether it would be a destructive or non-destructive analysis, what the purpose was, who was in the team and why you think you are capable of handling the particle. Then it was up to JAXA to decide whether or not it was a good proposal and whether they could send the sample to you.

Why did you call your sample 'Amazon'?

When we got the sample we thought it looked like South America because of the really elongated shape and that the different fragments within the particle looked like different countries within South America. We also found a really interesting carbon-rich grain located where the Amazon rainforest would be on the grain, so it's why we chose to call the sample Amazon.

What made your particle special?

We didn't really know whether there would be much organic material to study in the grain. It was really after we studied it in detail we thought, 'hey, we've found something really interesting'. Previously researchers have found organic molecules on samples, but they haven't been able to say whether it's terrestrial contamination or extraterrestrial organic molecules. Our analysis using isotopic analysis, with the NanoSIMS technique, was the first one which clearly showed extraterrestrial isotopic compositions that are definitely coming from asteroid Itokawa.

Did the ingredients for life come from asteroids?

This isn't the first identification of organic material on an asteroid. Through analysis of meteorites, researchers have found extraterrestrial organic material. The meteorites must have mainly been coming from asteroids, so this concept has been developed for decades. The first meteorite analysis that found amino acids was in the 1970s, so from that moment onwards people have been aware that we've got organic material coming from space.

Our analysis of a sample taken directly from Itokawa also showing organic material is just further evidence towards this idea that organic material could have been delivered to the early Earth by meteorites from near-Earth asteroids. We

© Queenie Chan

now want to know what the material looked like and what those materials are, and now people are working hard in building a linkage between raw ingredients to life. It's a huge mystery of how that material became life.

What's the underlying reason for researching asteroids in such detail?

We want to know what things were like on early Earth. But Earth is a very active planet. You've got plate tectonics melting rocks, you've got weathering processes constantly eroding material. We don't really know what it was like at the birth of the Solar System and how Earth really formed. We target asteroids because they're the 'building blocks' of planets. Asteroids haven't been melted in the past - they're in the same state as when they were formed. It tells us a lot about the origin and formation of our Solar System.

Is there an issue with collecting tiny samples?

You cannot use this to generalise the entire asteroid. For example, we found organic matter, but it doesn't mean that organic matter is everywhere in the sample. Particles from Itokawa have been distributed to different researchers around the world, and each researcher contributes a different idea to the entire picture. It's collective knowledge seeking. You cannot use one study to represent the entire Itokawa. Our study is just a small part of the far bigger picture.

Your team is now studying the samples from the Ryugu asteroid taken during the Hayabusa2 mission. Do you expect these to differ a lot from the samples studied from Itokawa?

From Hayabusa2 we know a lot from remote-sensing observations of Ryugu. We know that it is a carbon-rich asteroid, so we will probably see more organics in a sample from Ryugu compared to Itokawa, which is very exciting. From other analyses we speculate Ryugu has been heated in the past and that it contains absorbed water in the mineral structure, so it must be organic rich and also have been processed by water in the past, so that is also very interesting. We already know quite a lot about Ryugu from remote-sensing studies, but to really see the details, the messages that it is going to tell us about its history, we really need to study samples in our labs with our most sensitive instruments.

I would also like to say that the research we carry out would not be possible without the collaboration of the entire team. I don't take credit for the entire piece of work, as it wouldn't be possible without my collaborators' involvement. I am part of an excellent team, and it's really a collective effort that makes all this research possible.

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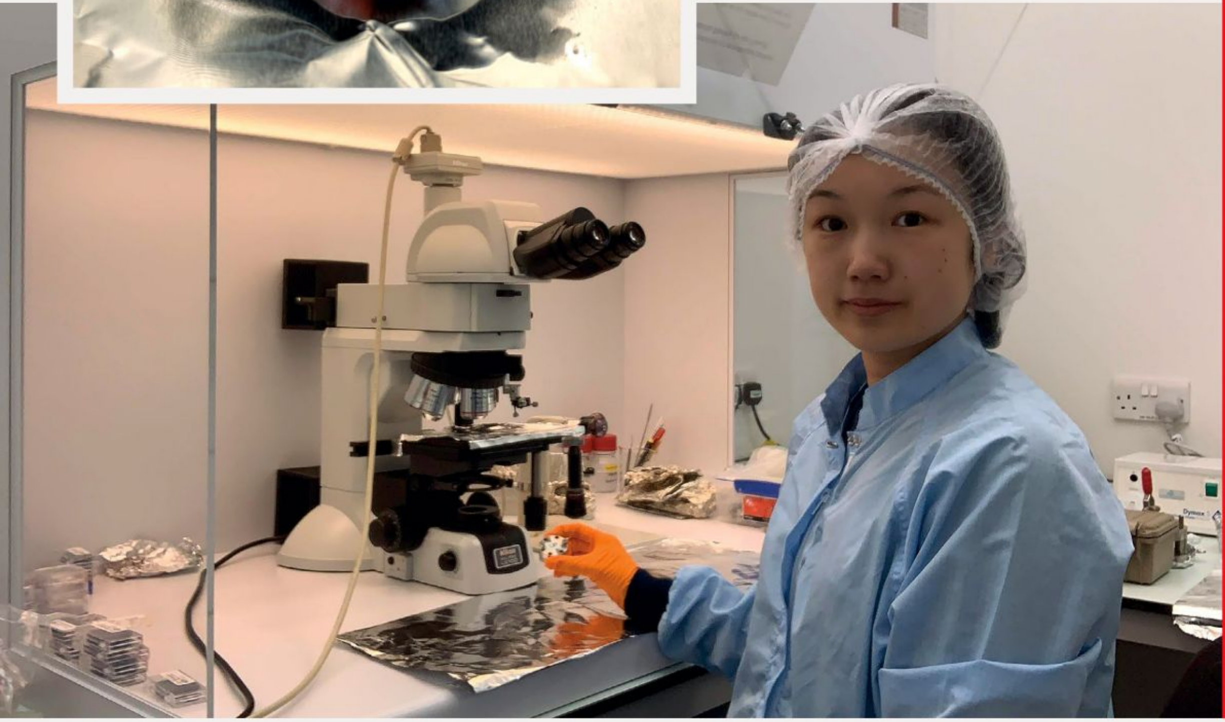
Left: Inside Hayabusa's sample container

Below: Chan in the lab with some of the equipment used to study the fragments



PERSEVERANCE ON MARS

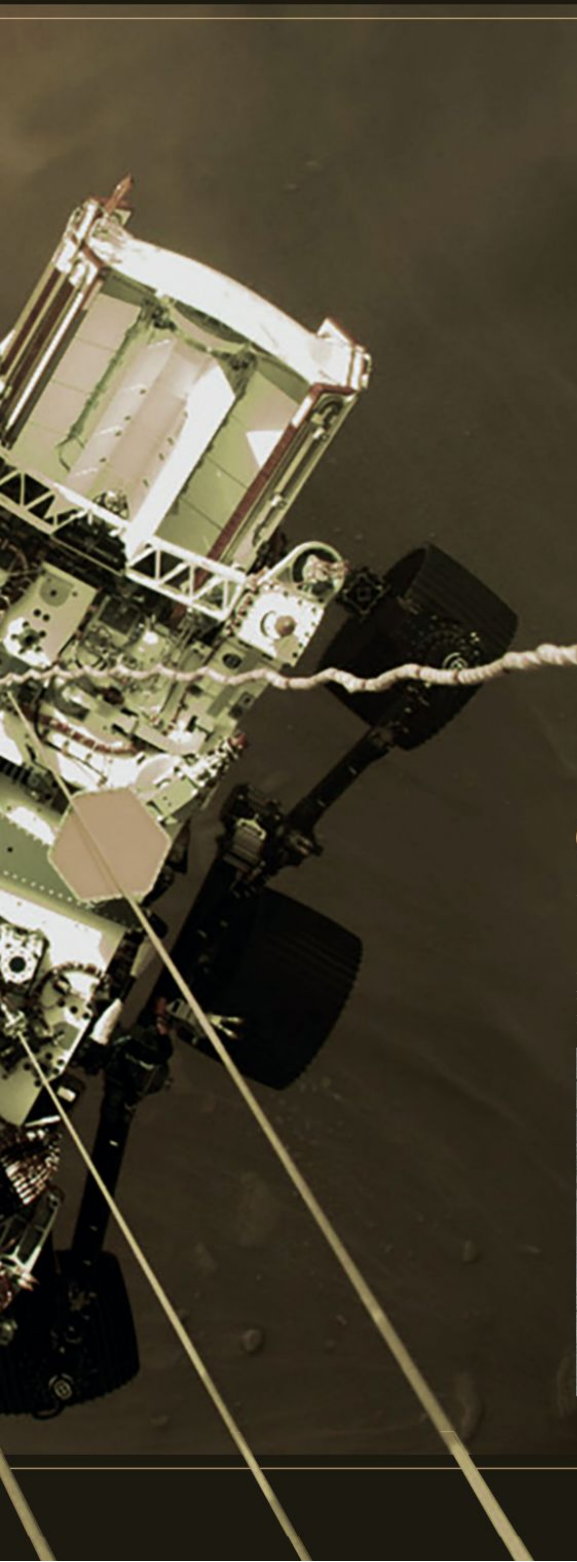
NASA'S LATEST MARTIAN ROVER HAS BEGUN ITS EPIC QUEST TO FIND EVIDENCE FOR PAST LIFE RESIDING IN JEZERO CRATER

Reported by Stuart Atkinson

Perseverance might not be the first rover to land on Mars – a small plaque mounted on it shows it is the youngest member of a 'family tree' of Red Planet rovers – but it is certainly the most capable so far. Almost groaning under the weight of cameras and scientific instruments, nuclear-powered Perseverance set down safely on Mars in a cloud of billowing orange dust on 18 February, and since then has begun to explore Jezero crater.

Perseverance's mission is simple and exciting: it's on a quest to look for evidence that Mars once had life. It will do that by studying rocks and material inside the crater, specifically within the layers of ancient sediment that form a striking, fan-shaped delta that pushes into the crater from the west. While it would be thrilling for the rover to spot a fossil sticking out of the rock, it's much more likely that any evidence it finds of past Martian life will take the form of chemical traces – blips on a chart. Perseverance will also collect samples of material from Jezero crater and leave them there for a future mission to collect and bring home for study using instruments that can't be taken to Mars. Perseverance is our best chance yet of answering one of the oldest, most exciting and tormenting questions in science: was there once life on Mars?

All Images © NASA



TOUCHDOWN

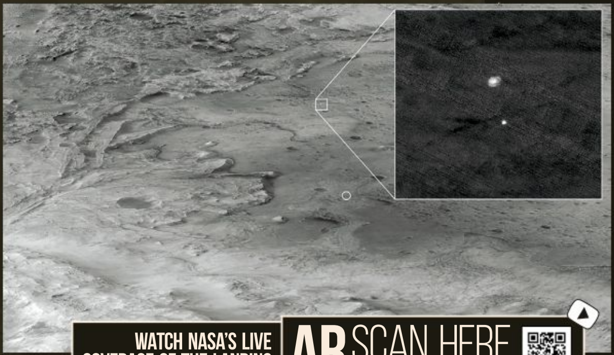
Because Perseverance and the support hardware used to land it safely on Mars were fitted with more cameras than any previous mission, we have been treated to some truly unique images, including this one showing the rover actually touching down on the surface of the Red Planet. This high-resolution still image is part of a video taken by several cameras that whirred and clicked away as the rover landed in Jezero crater. A camera aboard the descent stage captured this shot, which shows Perseverance surrounded by a billowing cloud of dust as its wheels touched the surface for the very first time. Also visible is the tether connecting the rover to the descent stage.

Left: Perseverance touches down on Mars in a swirling cloud of dust

Below: The MRO's HiRISE camera photographed Perseverance and its parachute dropping towards the landing site in Jezero crater

FALLING THROUGH THE MARTIAN SKY

In this immaculately timed image taken on 18 February 2021 by the High Resolution Imaging Science Experiment (HiRISE) camera aboard the Mars Reconnaissance Orbiter (MRO), the descent stage holding the Perseverance rover can be seen falling through the Martian atmosphere, with its parachute trailing behind. The image also shows the target of the Perseverance mission - an ancient river delta, entering Jezero crater from the left. Before Perseverance arrived, many professional and armchair scientists alike were hoping HiRISE would capture an image of it beneath its parachute, just as it photographed Curiosity's dramatic arrival a dozen years earlier. Taking this image required precise timing and a lot of clever flying by the MRO team.



WATCH NASA'S LIVE COVERAGE OF THE LANDING

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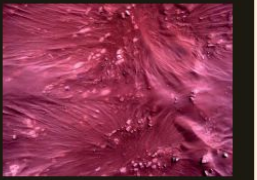
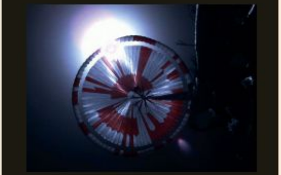


BLOWING AWAY THE DUST

The red colours and strange shapes visible in this striking image might make you think of something seen in the operating theatre of a hospital, but what it actually shows are streamers – whirls and curls of fine Martian dust being blown away from Perseverance's landing site as it was lowered down to the surface by its descent stage. It was taken by the camera mounted on the bottom of the rover.



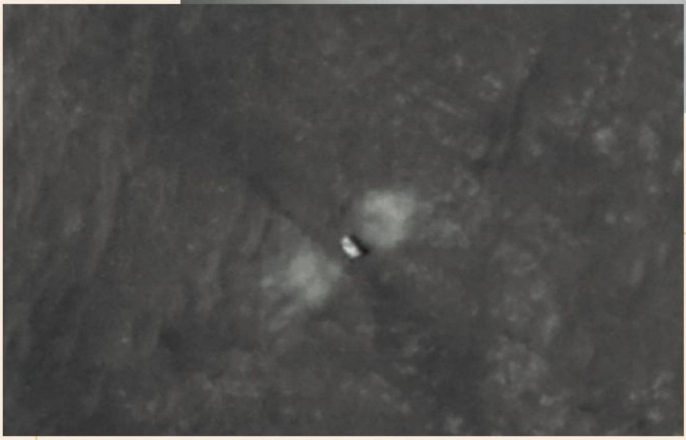
PERSEVERANCE'S PARACHUTE

Possibly one of the most striking images taken on landing day, this shows Perseverance's huge parachute lit from behind by the Sun. Hundreds of these images were taken, which were later combined to make a stunning video showing the parachute swaying and billowing in the wind. When this particular image was taken, the parachute was fully inflated, lowering the rover down gently to the surface. That pattern on the parachute isn't just a random collection of panels, however. It's a message, sneakily written in a special code, spelling out the Jet Propulsion Laboratory's motto: Dare mighty things.

THE HEAT SHIELD FALLS AWAY

This remarkable image, taken by Perseverance's Lander Vision System Camera (LCAM), shows the rover's heat shield dropping away towards Mars after being released from the back shell during the spacecraft's descent through the Martian atmosphere. This was the first use of the system at Mars, which compared images from below the spacecraft to an onboard map, helping to guide the spacecraft to a safe landing spot in Jezero crater. Past missions had deemed Jezero crater too hazardous to be a landing site because of its cliffs, dunes and boulders, but using LCAM the rover was able to find and steer itself down to a safe landing site close to the preserved remains of an ancient river delta. Without LCAM, a landing in such a 'busy' area would have been impossible.

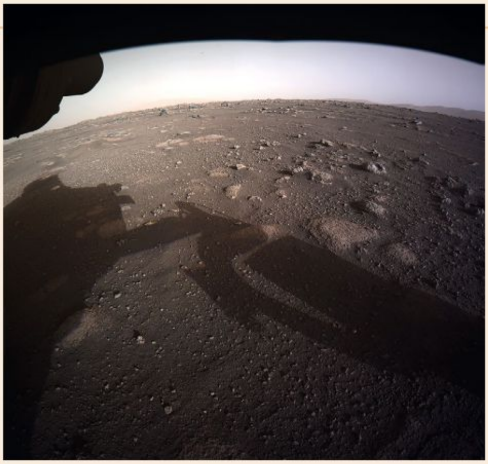
Right: Its job done, Perseverance's heat shield falls away



Left: Perseverance pictured on the ground, ready to begin roving across Mars

SAFELY ON THE GROUND

The HiRISE camera aboard NASA's MRO didn't just take an amazing image of Perseverance falling towards Mars on the end of its parachute; it also took this stunning view of the rover after it had landed on the surface. Taken the day after landing, this image is a close up taken from a larger image showing several different parts of the Mars 2020 mission landing system that got the rover safely on the ground. The bright 'fans' on either side of the rover are areas where the exhausts of the descent stage's engines blew away the dark dust from the surface, exposing lighter rock and material underneath.



Right: With the covers off its cameras, Perseverance could finally see the beauty of Mars for the first time

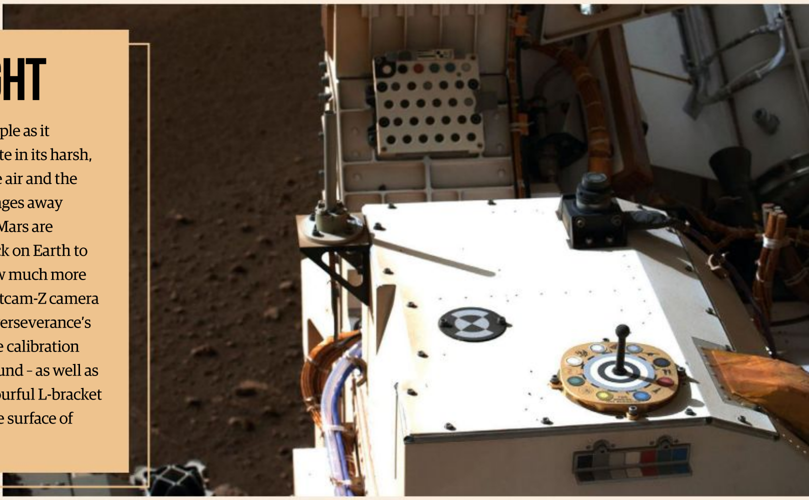
Below: Perseverance has several 'calibration targets' designed to help its science team balance the colour of the images taken by its suite of cameras

PERSEVERANCE OPENS ITS EYES

Very shortly after landing – even before the cheers in Mission Control had died down – Perseverance sent back a handful of images taken by the hazard avoidance cameras (hazcams) on its underside. But because the cameras still had their protective caps on to prevent them being damaged by dust kicked up during the landing, those images were blurry and indistinct. But soon those caps were popped off, and then Perseverance began sending back images like this: the first high-resolution colour image to be sent back after its landing. Now the mission scientists got their first proper look at the landing site, seeing a typically Martian scene – a vast, open plain littered with rocks beneath an orange-pink sky.

GET THE BALANCE RIGHT

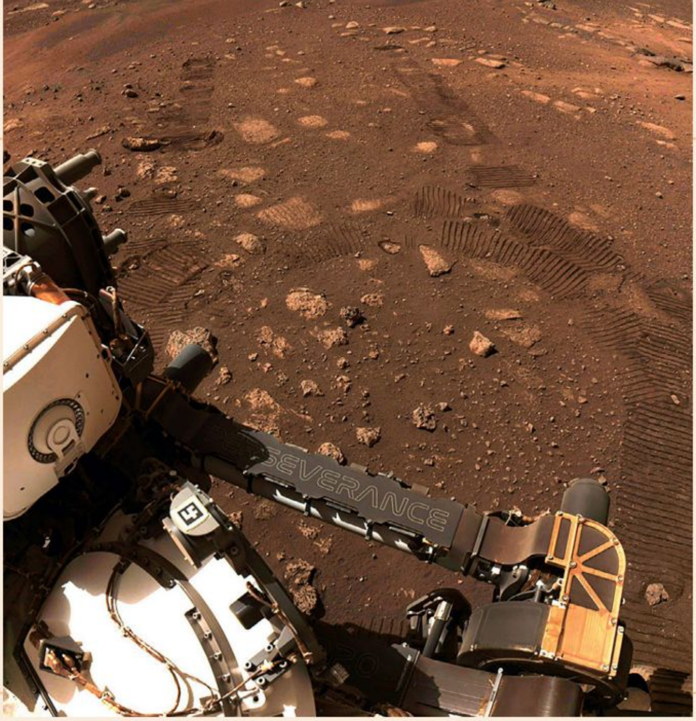
Taking pictures on the surface of Mars isn't as simple as it sounds. Very special cameras are needed to operate in its harsh, frozen environment, and then things like the dust in the air and the weaker sunlight there combine to shift the colour of images away from those the naked eye would see. Spacecraft sent to Mars are fitted with 'calibration targets' which allow the team back on Earth to balance the colours of their images and recreate the view much more accurately. This image, taken by the mast-mounted Mastcam-Z camera on 20 February 2021, the second Martian day, or sol, of Perseverance's mission, shows Mastcam's primary-colour and grayscale calibration target – the colourful, circular object in the right foreground – as well as the camera's secondary calibration target, the small colourful L-bracket just below the primary target. On the left you can see the surface of Mars, covered with rocks and dust.



FIRST DRIVE

Once a rover like Perseverance has landed safely on Mars, it can't just rev its engine and set off across the desert like it's starring in a Martian *Fast and Furious* film; its many systems have to be checked out thoroughly and patiently to ensure they weren't damaged during the descent and landing.

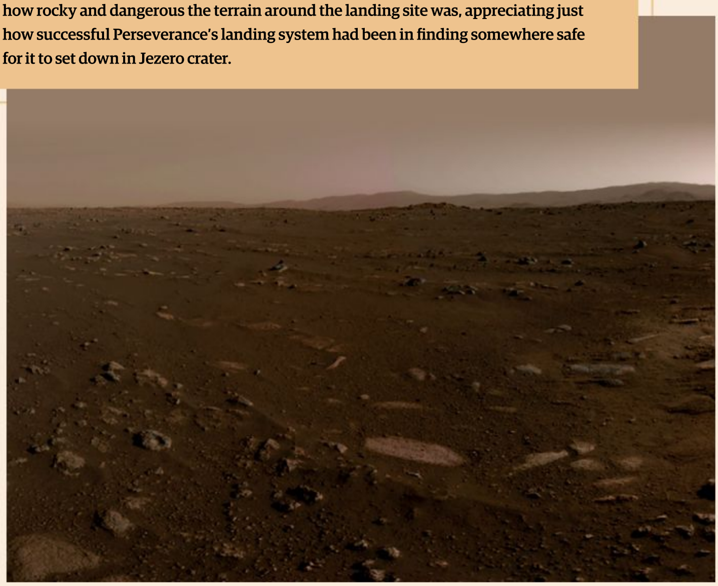
However, eventually it's time for the wheels to turn for the first time. On 4 March 2021, after weeks of preparation, Perseverance completed its first short drive. This image, taken by the rover's navigational cameras, shows the rover's first tracks on the dusty surface of Mars.



Left: Celebrations occurred as Perseverance left its first wheel tracks in the ruddy dust of Mars

FIRST COLOUR PANORAMA

This panoramic view, taken on 20 February by the navigational cameras, or navcams, aboard NASA's Perseverance rover, was stitched together from six individual images after they were sent back to Earth. It was the first time the mission scientists – and everyone following the mission around the world – realised how rocky and dangerous the terrain around the landing site was, appreciating just how successful Perseverance's landing system had been in finding somewhere safe for it to set down in Jezero crater.

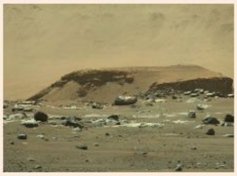


Left: Our first panoramic view of Perseverance's landing site

A FASCINATING FUTURE DESTINATION?

When the first images came back from Perseverance, they showed this intriguing feature – a remnant of the delta, detached from the main body, which many scientists are very keen to examine with Perseverance's suite of instruments. This hill of crumbling rock is about 2.3 kilometres (1.4 miles) to the west of the Perseverance landing site and is about 200 metres (660 feet) across. The image has been colour-balanced to show approximately what the scene would look like if we viewed it with human eyes.

Right: This remnant of the river delta might be visited by Perseverance later in its mission

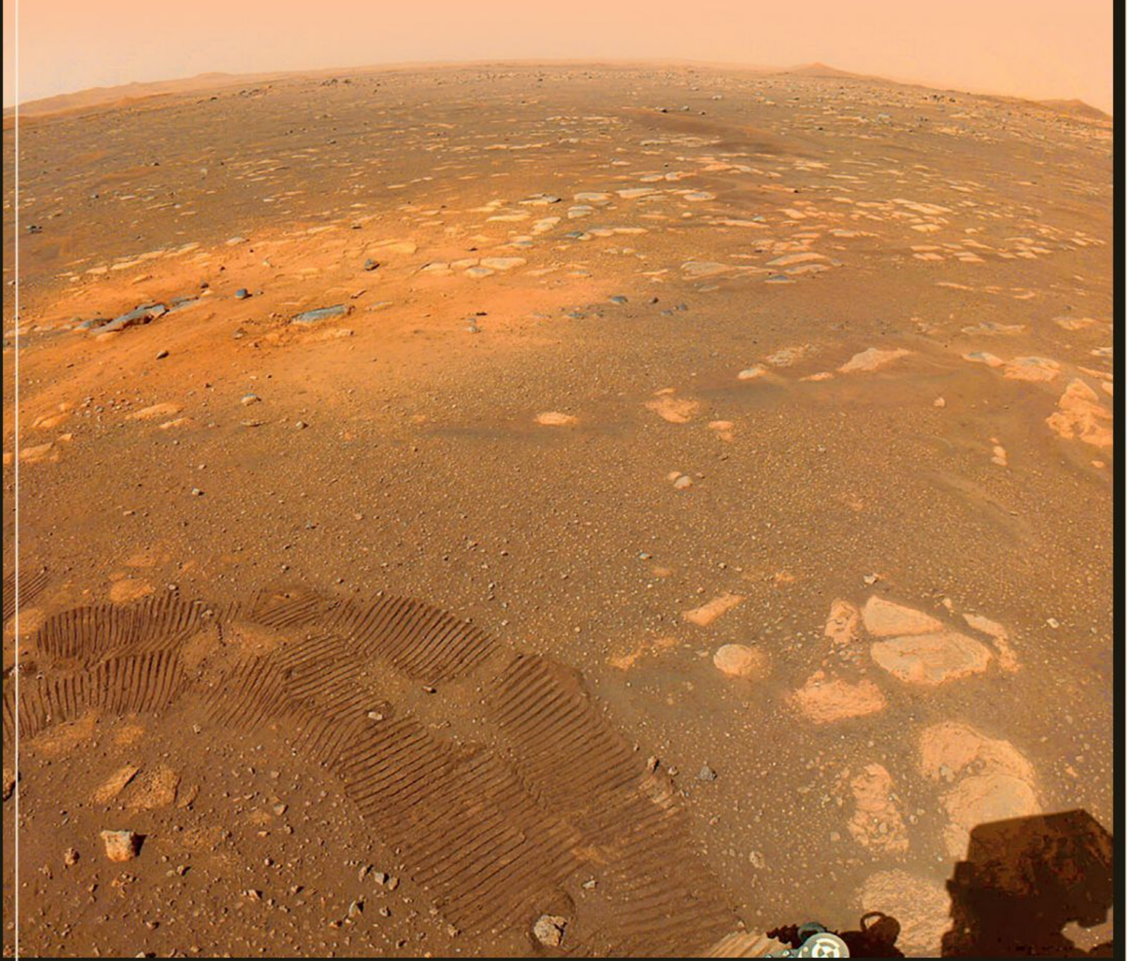


MARS IN 'REAL COLOUR'

If you stood next to Perseverance on the floor of Jezero crater, what would you actually see? Would it look as red or as pink as it does in the photos? This image, taken on 5 March 2021 by one of the rover's navigational cameras, was colour-calibrated to show the approximate view an astronaut standing on Mars would enjoy. It shows the tracks left on the dusty surface from the rover's first drive and an area scoured by the descent stage's rockets – the lighter coloured area in the middle ground – as it gently lowered Perseverance to the surface.

Below: Mars as your eyes would see it if you were standing beside Perseverance

ALL ABOUT THE PERSEVERANCE ROVER AR SCAN HERE



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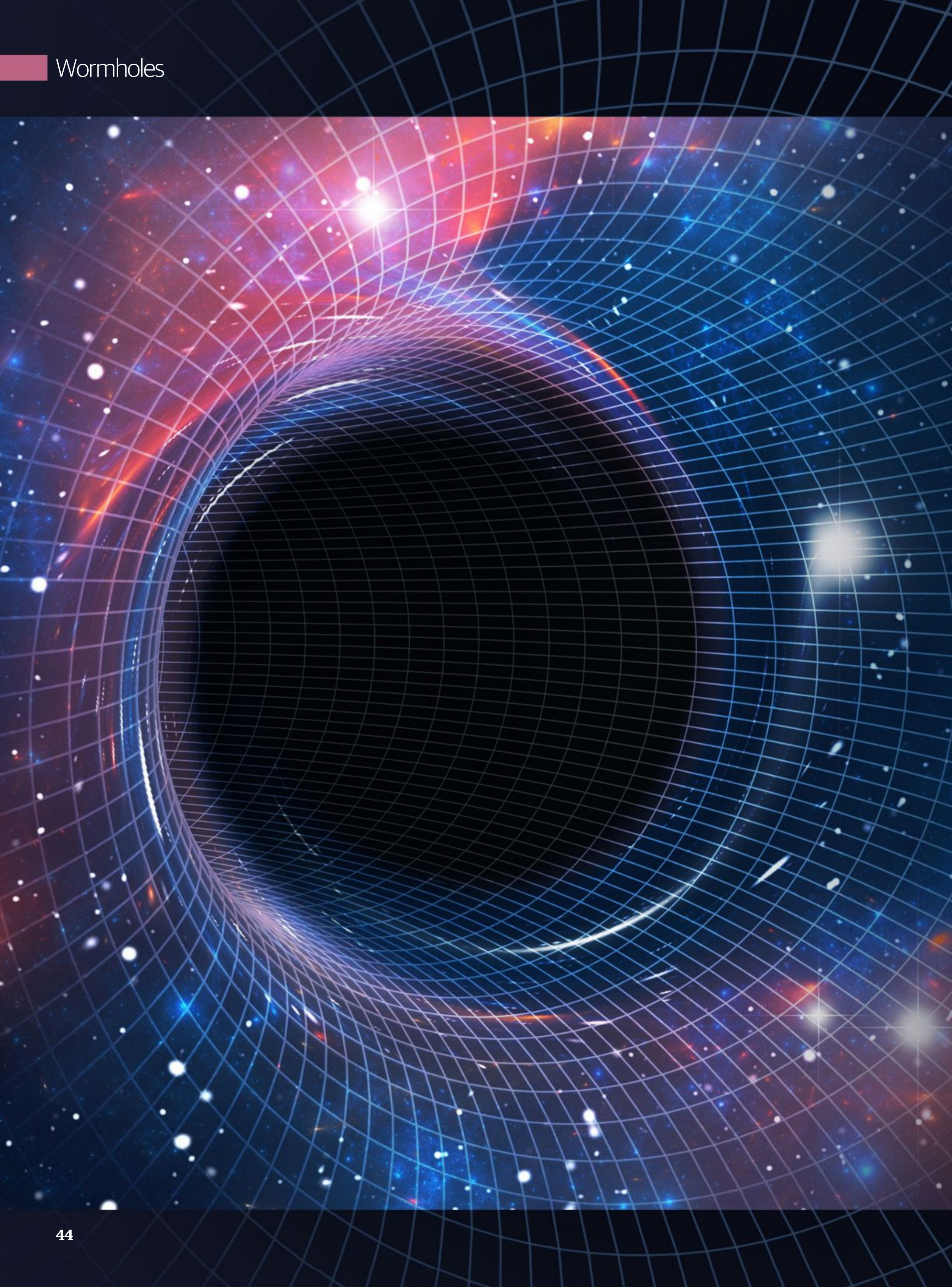


CAN WE DETECT WORMHOLES?

They're a staple of science fiction, but could they be real? New research suggests wormholes could be somewhere around us, and we could uncover them

Reported by Ian Evenden

We've all seen wormholes in science-fiction: openings in the very fabric of space through which spaceships can pass, opening up a method of faster-than-light travel in a universe that otherwise wouldn't allow it. These shortcuts in space-time can be natural or human-made, and their exits can send you into other realms of normal space-time or into hyperspace, a set of higher dimensions laying closely alongside our own, but through which we can travel more quickly than in normal space. Their profusion in fiction might suggest they're common.

In the set of dimensions we call reality, however, it's not so easy. Wormholes have not been observed, and remain speculative. They're consistent with Einstein's theory of general relativity, which allows space-time to be distorted by gravity. Black holes are one such special solution to the equations, and wormholes are another. As we've only just got our first good look at a black hole, it's entirely possible that wormholes could be out there somewhere, just waiting to be discovered.

"Wormholes are allowed in theory, and they have been intensely studied theoretically," says Dr Andreea Font of the Astrophysics Research Institute at Liverpool John Moores University. "They're mostly regarded as theoretical curiosities, and we don't actually have any tangible evidence of their existence."

When Einstein and fellow physicist Nathan Rosen were working together at Princeton in the mid-1930s, they produced an idea of layers of folded space-time connected by 'bridges' we would today call wormholes. Another name for one type of wormhole is an Einstein-Rosen bridge in tribute to their work. All they required to create this idea was the complicated maths of general relativity and Maxwell's equations, which cover electromagnetism. The pair would also go on to predict gravitational waves, but Einstein-Rosen bridges would be less of a success – they collapse so quickly nothing would ever be able to travel through them.

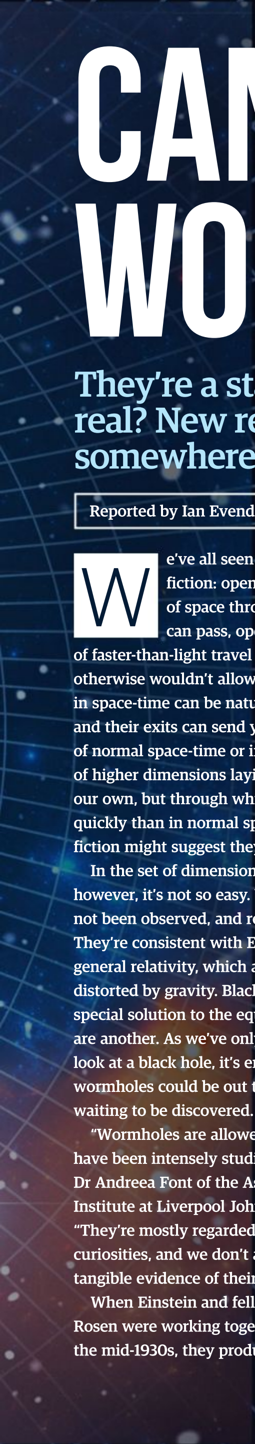
One problem with detecting a wormhole is telling it apart from a black hole. We just don't know enough about either type to label one definitely as a wormhole, while the other is 'merely' a black hole. The existence of a one-way event horizon may be a clue that an object is a black hole, but again we're in the world of pure theory. "We would like to know if there are any differences, but from the outside they may be indistinguishable," says Font. "However, they both act on their surroundings through gravity, so there might be some telltale signs. Some scientists have suggested that a wormhole could perturb the orbits of stars nearby in a different way than a black hole would. Some gravity would leak out from the other side through the wormhole, changing the orbits of stars just enough to be noticeable.

"Obviously they don't emit any light, but they could affect the light of the optical material that's falling in or coming out. For example, there have been some suggestions that gamma rays might look different coming from a wormhole rather than a black hole, but we don't have consistent studies of the observational signatures of wormholes the way we do of some black holes, and we can't distinguish the two."

What makes things harder is that there may be different types of wormhole. There are some

Right: The centre of our galaxy contains a star known as S2, which is being studied to see if a wormhole is changing the way it orbits

© NASA



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SEEKING OUT WORMHOLES

It's currently impossible to tell the difference between a wormhole and a black hole, but there are ways it could be done

1 Gravitational lensing

In 2008, two scientists from Gurucharan College, Silchar, India, investigated whether wormholes could, like black holes, exhibit gravitational lensing of light that passes by them. They discovered that one type of wormhole, the Ellis drainhole, the earliest known complete mathematical model of a traversable wormhole by Homer G. Ellis, and separately Kirill A. Bronnikov, does not exhibit this lensing. Therefore a black hole-like structure that doesn't bend light might well be a wormhole.

© NASA

2 Leaky gravity

If a wormhole enters our universe, or our part of the universe, and there is mass on the other side of it, then it will generate gravity. This can pass through the wormhole and add to the gravitational pull, either perturbing the orbits of objects around the wormhole mouth or adding to its pull so it appears to exert more gravity than its size would account for. Having too much gravity could make a wormhole stand out from otherwise identical black holes.

© NASA

3 Gamma rays

Research from scientists in Saint Petersburg, Russia, has shown that while black holes, particularly those at the centre of active galaxies, can release gamma rays as a relativistic jet, the rays released from a wormhole are more likely to be in a sphere, as it has no event horizon. This radiation would also have a distinct spectrum, acting as a marker to tell the different types of hole apart.

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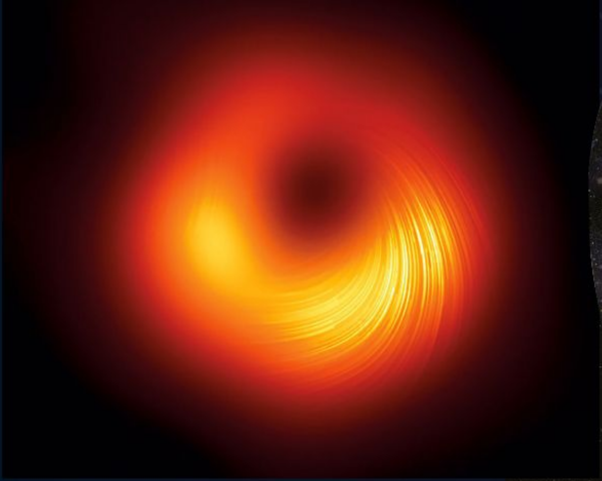

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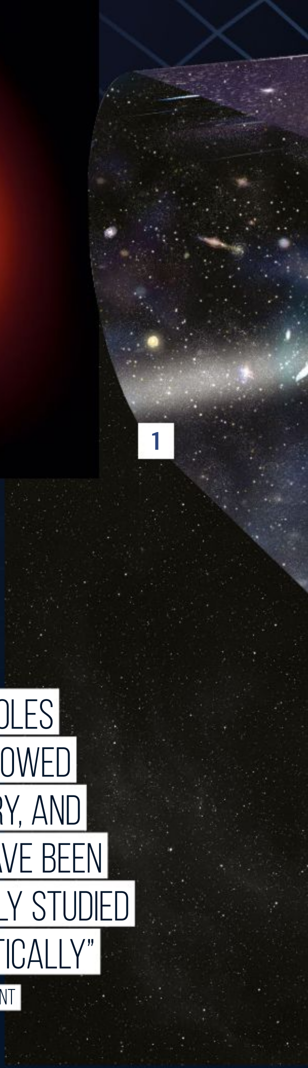
Above: The supermassive black hole at the centre of galaxy M87



that link different points in the same universe, possibly billions of light years apart. Some could link different points in time, as general relativity sees time as the fourth dimension of space-time. Others could punch through between different universes, particularly in brane cosmology, which sees universes form on four-dimensional sheets within 11-dimensional space.

"There could be microscopic, very tiny wormholes, and there could be very big ones," says Font. "If there are holes that are very big, they could potentially be at the hearts of massive galaxies. Some have suggested that the centre of mass of galaxies could be supermassive black holes, but with a wormhole hidden in there too. But we would need an additional sign - an extra piece of evidence that is not explained by black holes - in order to reach the conclusion that it could be a wormhole."

Even the black hole at the centre of our own galaxy, Sagittarius A* (Sgr A*), has been nominated as a wormhole candidate. Dejan Stojkovic, professor of physics at the University at Buffalo, has studied a star called S2 that orbits Sgr A*, looking for deviations in its orbit that could be ascribed to a wormhole: "If you have two stars, one on each side of the wormhole, the star on our side should feel the gravitational influence of the star on the other. The gravitational flux will go through the wormhole," said Stojkovic.

"When we reach the precision needed in our observations, we may be able to say that a wormhole is the most likely explanation if we detect perturbations in the orbit of S2," he continues. "But we cannot say 'this is definitely a wormhole'. There could be some other explanation, something else on our side perturbing the motion of this star."

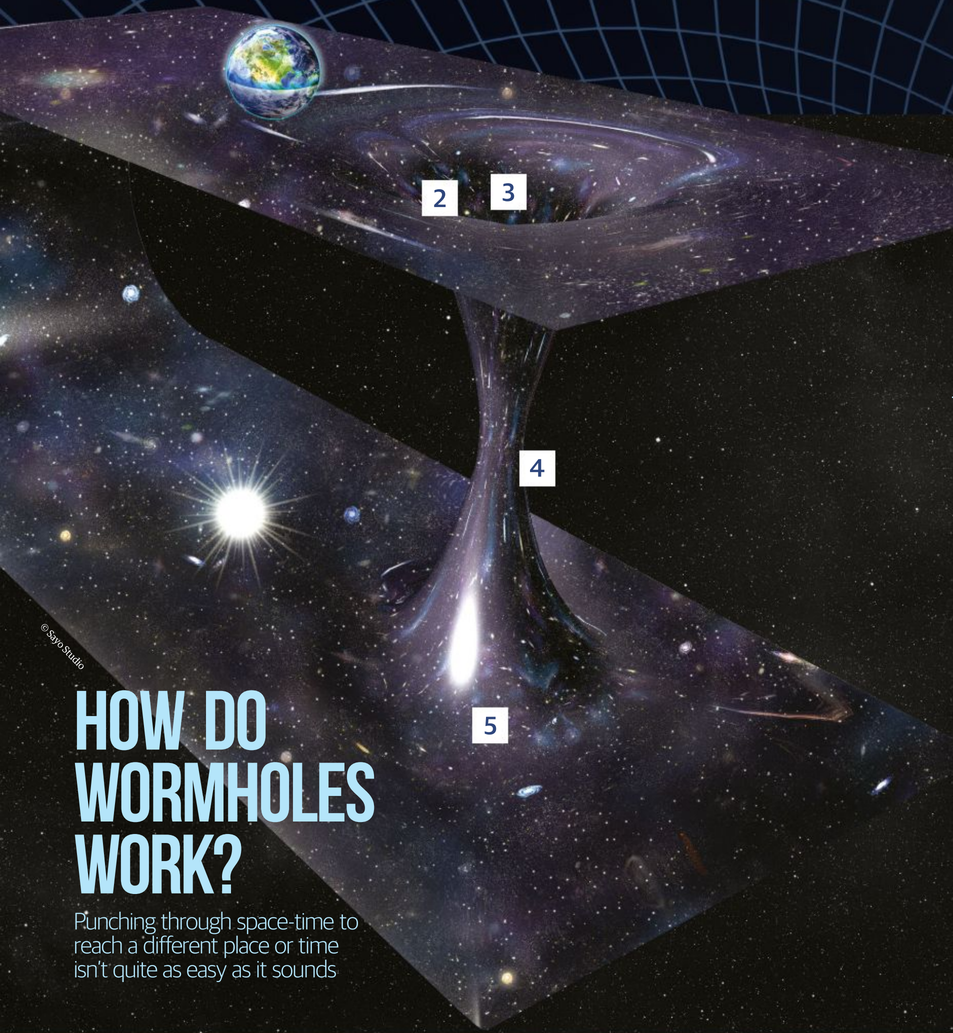
The problem is still a lack of data. "If the wormhole is always connecting with, let's say, another part of the universe where there's some matter on the other side," says Font, "that matter would exert some additional gravitational pull on the stars orbiting around the Milky Way, or the centre of the Milky Way, and that would change their orbits very slightly. But unfortunately at the moment our instrumentation is not good enough to detect this additional perturbation, so this is just speculation."

Supermassive black holes certainly live up to their name, with one of the largest known specimens - which powers the TON 618 quasar - a supercolossal 66 billion times the mass of the Sun. Sitting 10,400 million light years away, the quasar is the light emitted by the accretion disc of a black hole at the centre of a galaxy we can't see. It shines with the brightness of 140 trillion Suns, and outshines the light from its entire home galaxy. Its event horizon - or Schwarzschild radius - is thought to be 40 times the distance from the Sun to Neptune. The

> "WORMHOLES ARE ALLOWED IN THEORY, AND THEY HAVE BEEN INTENSELY STUDIED THEORETICALLY"
>
> DR ANDREEA FONT

HOW DO WORMHOLES WORK?

Punching through space-time to reach a different place or time isn't quite as easy as it sounds



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1 Curved space-time

One form of wormhole relies on curved space-time to function. To us, as three-dimensional beings, it appears flat, but curves in the fifth dimension – or greater – to fold back on itself.

2 Entrance

The wormhole entrance looks just like a black hole. There may be an accretion disc made up of matter falling into it.

3 Singularity

In a rotating black hole, the singularity occurs as a ring or line rather than a point. This is what provides the gravity required to sink the wormhole through space-time.

4 Exotic matter

Keeping the wormhole open against the gravitational forces causing it to collapse requires some negative energy or anti-gravity we have yet to discover. Quantum effects within curved space-time may be able to violate the averaged null energy condition, keeping it open.

5 Exit

The exit looks the same as the entrance. Unlike a black hole, from which nothing can escape, forces and even matter may be able to exit from a wormhole.

thing is big, but it's still a black hole – there's no evidence of anything else going on.

Another giant black hole resides at the centre of Messier 87, and this was recently imaged in polarised light by the Event Horizon Telescope to show the orientation of its magnetic field at its edge. The dark area of the hole itself is an oval rather than circular in the image, thanks to its rotation. Before scientists referred to an 'event horizon' or 'Schwarzschild radius', they sometimes used the phrase 'Schwarzschild throat,' which suggests a structure that could be passed through. The work of physicist Roy Kerr in the 1960s suggests that it would be impossible to stand still when around a spinning black hole, as space-time itself is literally dragged around by the spinning, which changes the shape we see to an oblate spheroid. "Some people have tried to apply their theories to the black hole at the centre of M87 and work out what would be the consequence of a wormhole there, but it has never happened the other way round, of actually observing something that could be an unmistakable sign of one," says Font.

The hunt is on, not just for wormholes, but traversable wormholes too. Previous solutions to this problem have called for exotic matter with properties that resist the gravitational collapse – usually negative energy, which has yet to be discovered. Recent work from Jose Blázquez-Salcedo from the Complutense University of Madrid and his colleagues, however, has discovered a way to bypass the inconvenient negative energy by assuming that matter interacts through electromagnetic fields, and is described as quantum wave functions. Satisfy

Right: Artist's illustration of a galaxy with jets from a supermassive black hole

© ESA/Hubble

all these conditions, and a traversable wormhole becomes possible.

However, there's another catch: the wormhole is traversable, but not by humans. The researchers added Paul Dirac's theory of quantum particles to general relativity and Maxwell's equations, meaning anything entering the wormhole would need to be in a quantum state - effectively limiting it to microscopic groups of atoms.

Further work by Juan Maldacena and Alexey Milekhin out of Princeton suggests a different method of creating a human-traversable wormhole. It requires a model of physics beyond the Standard Model - the five-dimensional Randall-Sundrum model - but under these conditions a human could traverse a wormhole, travelling across the galaxy in under a second. To observers outside the wormhole, however, the journey would appear to take thousands of years. All of which is fine, as long as you can detect the wormhole in the first place, which is still proving difficult. Research from a team led by James B. Dent of Sam Houston State University, Texas, could lead to their detection, but only if a very specific thing happens.

It requires a black hole to pass through a wormhole. This may seem unlikely, but recent gravitational-wave detections have come from merging black holes, so it's not impossible for a black hole and a wormhole to run into one another - if the latter exists, at least. The theoretical wormhole here is one between two universes, and as a black hole spiralled into it, it emitted the same gravitational waves as if two black holes had merged. What was different, however, was that when the black hole exited the wormhole on the other side, there was a cough, a distinct gravitational-wave emission that was different from that generated by a merger. We've only just started picking up gravitational waves, so it could be a while before we detect this rare event, if it ever happens.

It's not just other universes that wormholes could connect to - what about other times? There's nothing to stop this. Time travel is "accepted in special and general relativity. For example, when we travel near to the speed of light, we know that time slows down," says Font.

The issue here is that while time travel to the future is fine, time travel to the past is fraught with problems. Stephen Hawking was adamant that the laws of physics would prevent backward time travel, and as Font points out, doing this could unleash a paradox: "If someone could travel into the past and emerge from the wormhole in the same spatial position, but at an earlier time, then they would be able to alter history, and they could even alter their own existence." This is the famous 'grandfather paradox', but we still don't know if the events of the past could be altered in this way.

Until the news breaks that scientists have detected a wormhole, seen that it is distinct in some way from a black hole and discovered that humans can travel through it, all of this lives in the realm of the highly theoretical. It's the exciting consequences of their existence - time travel, faster-than-light travel and trips to different universes - that keeps them in our collective imagination, however, along with the inevitable Nobel prize for their discoverer.

Ian Evenden
Space science writer
Ian has been writing about the universe for over ten years, focusing on cosmology and space exploration. He's also a keen astrophotographer.

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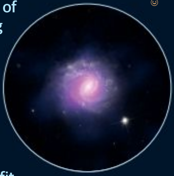
Left: An artist's impression of a wormhole opening

WORMHOLE CANDIDATES

Active galactic nuclei

The supermassive black holes at the centres of galaxies are candidates for investigators looking for wormholes. The motions of their orbiting stars and their gamma-ray output are being scrutinised for anything that doesn't fit.



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Quantum foam

If you were able to put space-time under a powerful microscope, there's no reason that it should appear smooth. Quantum mechanics holds that particles spontaneously appear and disappear, and the same could be true of wormholes.

© NASA

Ordinary black holes

According to the Penrose diagram of a Schwarzschild black hole, an object that is already travelling faster than light when it enters a black hole will emerge in a different space, time or universe, effectively turning it into a wormhole.

© NASA

Entanglement

One theory holds that wormholes are two entangled black holes, set back to back rather than merging into a single larger one. The ER = EPR conjecture holds that all entangled particles are joined by a wormhole, and this may go some way to unifying general relativity and quantum mechanics.

© Getty

RARE SUPERNOVA RELIC FOUND IN OUR GALAXY

NASA's Chandra X-ray Observatory has discovered the remains of something quite unusual within the Milky Way's heart

Supernovae are stellar explosions that seed the galaxy with the elements vital for life. Sagittarius A East (Sgr A East) is a supernova remnant that lies near Sagittarius A*, the supermassive black hole at the centre of the Milky Way. According to a statement from the Chandra X-ray Observatory, this supernova remnant is the first known example of an unusual type of white dwarf stellar explosion called a Type Iax supernova.

"While we've found Type Iax supernovae in other galaxies, we haven't identified evidence for one in the Milky Way until now," said Ping Zhou from Nanjing University in China. "This discovery is important for getting a handle of the myriad of ways white dwarfs explode."

There are different types of stellar explosions, ranging from those triggered by the collapse of massive stars to those that are triggered by smaller white dwarf stars that have pulled too much material from a companion star or collided with another white dwarf.

White dwarf explosions - generally designated as Type Ia supernovae - are an important source of chromium, iron and nickel in the universe. However, using the Chandra observations, astronomers found Sgr A East produced different relative quantities of essential elements and created a less powerful explosion than a typical Type Ia supernova, suggesting it is instead a Type Iax supernova.

"This result shows us the diversity of types and causes of white dwarf explosions and the different ways that they make these essential elements," said Shing-Chi Leung from the California Institute of Technology. "If we're right about the identity of this supernova's remains, it would be the nearest known example to Earth."

© NASA

"WHILE WE'VE FOUND TYPE IAX IN OTHER GALAXIES, WE HAVEN'T IDENTIFIED EVIDENCE FOR ONE IN THE MILKY WAY UNTIL NOW" PING ZHOU

TIAN

A SYMBOL OF CHINA'S TECHNOLOGICAL PROWESS AND THE VALUE OF GLOBAL SCIENTIFIC CORROBORATION

Reported by Daisy Dobrijevic

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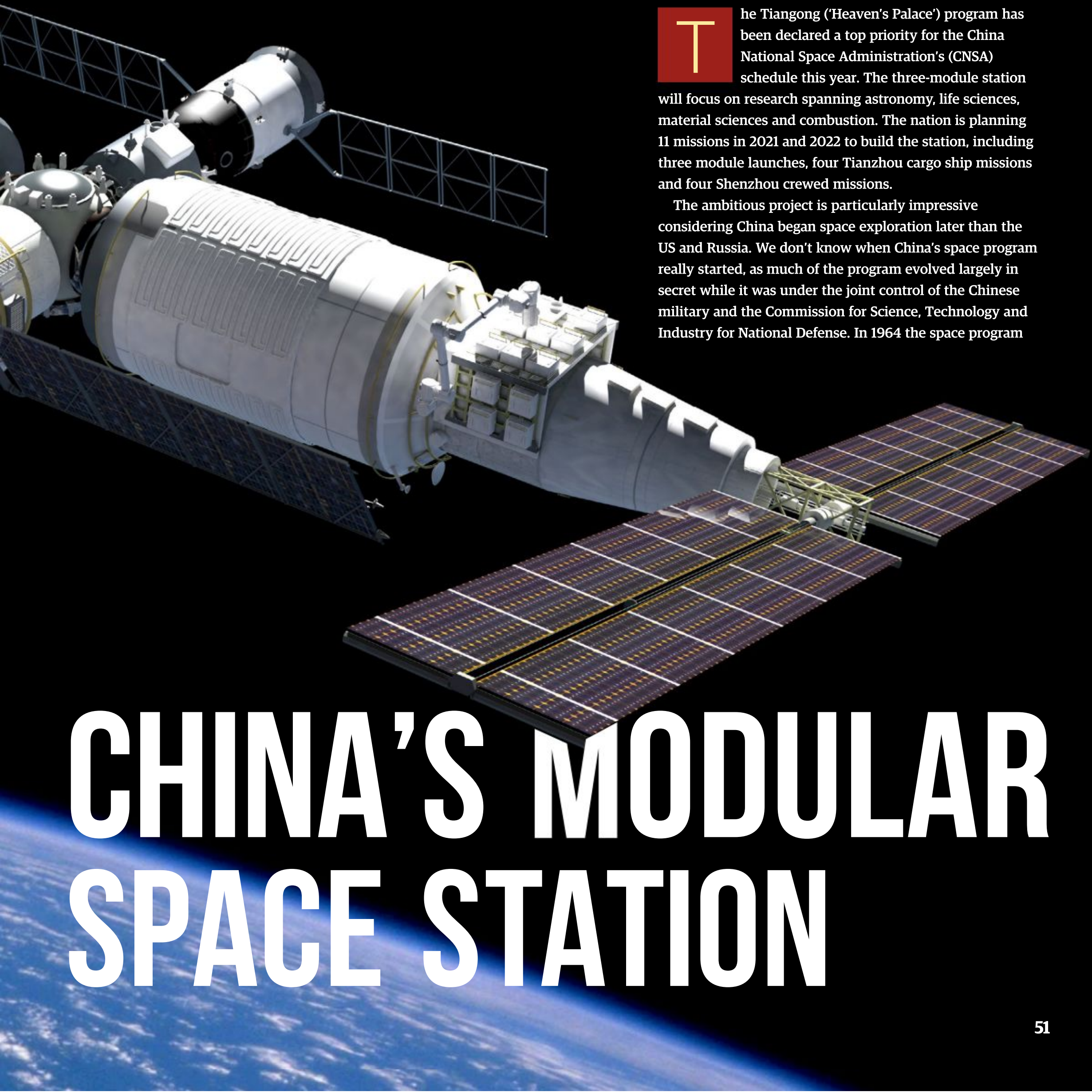
GONG

CHINA'S MODULAR SPACE STATION



The Tiangong ('Heaven's Palace') program has been declared a top priority for the China National Space Administration's (CNSA) schedule this year. The three-module station will focus on research spanning astronomy, life sciences, material sciences and combustion. The nation is planning 11 missions in 2021 and 2022 to build the station, including three module launches, four Tianzhou cargo ship missions and four Shenzhou crewed missions.

The ambitious project is particularly impressive considering China began space exploration later than the US and Russia. We don't know when China's space program really started, as much of the program evolved largely in secret while it was under the joint control of the Chinese military and the Commission for Science, Technology and Industry for National Defense. In 1964 the space program was managed by the Seventh Ministry of Machine Building, which in 1983 became the Ministry of Aerospace Industry. In 1993 the CNSA was officially founded, roughly 34 years after NASA, when the ministry was split into the CNSA and the China Aerospace Science and Technology Corporation (CASC). While the CNSA is largely responsible for policy, the CASC is responsible for the execution of procedures, including Tiangong.

China's modular space station will be about one-sixth the size of the International Space Station (ISS), a project that China has been unable to get involved with since being banned from the venture by the US in 2011. Though it is unclear exactly why the US decided to ban China, it is speculated that China's fledgling space agency was seen as too inexperienced to contribute significantly to the ISS, and with additional security concerns raised by the US, China was prevented from even setting foot on the station.

Despite the US freezing China out of space cooperation opportunities, it hasn't stopped the nation from making substantial progress in the space sector. In fact, the tables could turn in the near future, as the ISS is nearing the end of its operational life just as Tiangong will be starting out. Though Tiangong will be a fraction of the size of the ISS, there may come a point in time in which it is the only space station in operation, making it a very valuable commodity. How this could influence both exploration and research in space is yet to be determined, as there is currently no formal end date for ISS operations. "While the ISS is currently approved to operate through at least December 2024 by the international partner governments, from a technical standpoint we have cleared the ISS to fly until the end of 2028," said NASA officials.

Left: Construction of the Long March 5B rocket that will launch the core module, called Tianhe

©CMSA

Previously shunned from being a part of the ISS, and now with more than 40 missions planned just this year by CASC, China is no longer stuck on the sidelines of space exploration. China is making good progress on its space station, with the core module Tianhe ('Joining of the Heavens') recently passing a flight acceptance review and scheduled to be launched in spring 2021, though China has not yet announced a definitive timeline. After Tianhe has been successfully launched into orbit, an uncrewed Tianzhou supply mission will visit the module. The Tianzhou 2 spacecraft has also passed its flight readiness review, and will be launched to Tianhe aboard a Long March 7 rocket from the Wenchang Spacecraft Launch Site.

After the Tianhe launch and cargo mission, the first crewed mission to the core module will take place. This will be the first of four construction missions to the space station, whereby three taikonauts will help prepare Tianhe and ready the module for docking with a further two modules.

On 1 October 2020, China announced a group of 18 taikonauts that will be participating in the nation's space station project. The group consists of seven pilots, seven spaceflight engineers and four payload specialists, though the identities of those selected have not yet been released. This recruitment process took a couple of years, with 2,500 candidates whittled down to just 18. The new recruits will join fellow taikonauts who were chosen in previous recruitment rounds in 1998 and 2010, where only air force pilots were permitted to apply.

ACCEPTED EXPERIMENTS

POLAR-2: GAMMA-RAY BURST POLARIMETRY ON THE CHINA SPACE STATION

POLAR-2 will build on a previous investigation from Tiangong-2 and will continue the study of gamma-ray bursts. This astronomy project involves four institutions from four countries: the University of Geneva, Switzerland; the National Centre for Nuclear Research, Poland; the Max Planck Institute for Extraterrestrial Physics, Germany and the Institute of High Energy Physics of the Chinese Academy of Sciences.

SPECTROSCOPIC INVESTIGATION OF NEBULAR GAS (SING)

The SING instrument's primary goal is to generate spectral maps of the sky using an ultraviolet long-slit spectrograph, though it will be constrained by the orbital inclination of the space station. This experiment will be carried out by two institutions from two countries: the Indian Institute of Astrophysics and the Institute of Astronomy of the Russian Academy of Sciences.

BEHAVIOUR OF PARTIALLY MISCIBLE FLUIDS IN MICROGRAVITY

This research will investigate how fluids mix under different temperature and microgravity conditions. It will be implemented by the Indian Institute of Technology and the Université libre de Bruxelles in Belgium.

FLAME INSTABILITIES AFFECTED BY VORTICES AND ACOUSTIC WAVES (FIAVAW)

This is an experiment in microgravity fluid physics and combustion. It will investigate the fundamental problems of flame stabilisation in a convective flow. This research is of particular importance to aircraft and rocket engine combustion, as well as fire safety issues in space. It will be jointly carried out by Tsinghua University, Beijing, China and the University of Tokyo, Japan.

TUMOURS IN SPACE: SIGNATURES OF EARLY MUTATIONAL EVENTS DUE TO SPACEFLIGHT CONDITIONS ON 3D ORGANOID CULTURES DERIVED FROM INTRA-INDIVIDUAL HEALTHY AND TUMOUR TISSUE

This will study the effect of gravity on tumours, looking at whether tumours stop growing in microgravity conditions, and also assess the impact of cosmic radiation on cancer risk for astronauts on long space missions, such as a trip to Mars.

EFFECT OF MICROGRAVITY ON THE GROWTH AND BIOFILM PRODUCTION OF DISEASE-CAUSING BACTERIA

This will investigate the differences between the growth and biofilm production of bacterial colonies grown on Earth and those on board the space station. Biofilms are a collective of one or more types of microorganism that can grow on a variety of surfaces – an example being biofilm dental plaque, which is a build-up of bacteria on the surfaces of teeth.

The increased 'diversity pool' of this latest drive reflects China's changing needs for the construction and operation of a modular space station. A space station requires a consortium of specialists who can perform a variety of tasks, from control and management of the spacecraft to carrying out a diverse range of experiments spanning astronomy, Earth observation, medical sciences, material sciences and microgravity physics.

According to the China Manned Space Agency (CMSA), selection of subsequent batches will be carried out in due course, though there are no details on selection criteria. The latest recruits are undertaking extensive training so they are ready to join the operational phase of the space station, while active taikonauts from earlier recruitment rounds are preparing for upcoming missions and extra-vehicular activities. They will be involved in the first missions to Tianhe, as well as construction missions involving the two experimental modules Wentian ('Quest for the Heavens') and Mengtian ('Dreaming of the Heavens').

The modules, each weighing around 20 tonnes, will be delivered separately to Tianhe by the Long March 5B, which can lift up to 23 tonnes. The first demonstration flight of the rocket was successfully carried out in May 2020, with this uncrewed test flight providing China with valuable performance data on crucial components such as heat shields and parachutes. Final testing of the rocket is currently underway in Tianjin in northeastern China, after which the components of the rocket will be transported by cargo ship to the launch site.

Once all three modules are fully assembled, the space station will weigh around 90 tonnes. This

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Above: Prelaunch preparations are underway for the Long March 2F

Right: The Shenzhou 9 spacecraft and its carrier rocket are moved to the launch platform

CONDITIONALLY ACCEPTED EXPERIMENTS

MID-INFRARED PLATFORM FOR EARTH OBSERVATIONS

This Earth science project will use two mid-infrared cameras for Earth observation. The research aims to build on our knowledge of atmospheric humidity flows and improve the forecasting of heavy precipitation and hurricanes. The project will be jointly run by two organisations from Mexico: the National Institute of Astrophysics, Optics and Electronics and Benemérita Universidad Autónoma de Puebla.

DEVELOPMENT OF MULTI-JUNCTION GAAS SOLAR CELLS FOR SPACE APPLICATIONS

The main aim of this project is to develop high-efficiency solar cells for future space applications. This space-utilisation technology project will be jointly implemented by two institutions from Saudi Arabia: the National Centre for Nanotechnology and Advanced Materials and the King Abdulaziz City for Science and Technology.

BARIDI SANA: HIGH-PERFORMANCE MICRO TWO-PHASE COOLING SYSTEM FOR SPACE APPLICATIONS

This microgravity fluid physics and combustion proposal aims to research and test the next generation of cooling systems that use an organic and non-toxic cooling agent. This is a novel concept, and is therefore of high value for human space exploration systems, as well as potentially reducing the carbon footprint of cooling systems on Earth.

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impressive project has been a long time in the making. In 1992 the Chinese National Manned Space Program was given the designation Project 921. The 92 represented the year it began, and the 1 designates that it is the first major long-term national project started that year. Project 921 was broadly divided into three phases, which included a crewed launch mission followed by a temporary space station and then finally the construction of a permanent space station.

The first phase of Project 921 was achieved on 15 October 2003 when taikonaut Yang Liwei was launched into space aboard the Shenzhou spacecraft by a Long March 2F rocket. Yang spent 21 hours in space and orbited Earth 14 times before returning aboard the re-entry module and touching down near a landing site in Inner Mongolia. Two years later the Shenzhou 6 mission marked the sixth flight of the Shenzhou module and the second crewed flight for the Chinese space program. During this mission two taikonauts, Fei Junlong and Nie Haisheng, orbited Earth 75 times over near five days before returning safely to Earth.

These missions demonstrated that China has a good grasp of the technology needed to put humans safely into space, and marked the last mission of the first phase. China then began work on phase two, during which the nation launched two prototype space labs: Tiangong-1 in 2011 and Tiangong-2 in 2016. Both space labs were visited by taikonauts aboard Shenzhou spacecraft, helping to demonstrate the capabilities of the technologies required for the construction of the Tiangong modular space station. In 2017 China was able to test autonomous refuelling in microgravity by using the Tianzhou 1 spacecraft to dock and refuel Tiangong-2 in low-Earth orbit. This was a particularly important milestone in the Chinese space program, as the future space station will need to be able to replenish fuel supplies that are spent when the station needs to occasionally raise its orbit to counter the effects of atmospheric drag.

These two temporary space labs paved the way for a permanent modular space station, demonstrating China's technical capabilities with regards to spacecraft construction, but also the importance of conducting scientific research in space. Phase two was therefore considered complete, and Tiangong-1 and Tiangong-2 were deorbited in April 2018 and July 2019 respectively, burning up upon re-entry over the Pacific Ocean. Phase three is now well underway, with the proposed launch of Tianhe in spring this year.

Building upon the foundations of the two temporary space labs, China encouraged researchers from around the world to send in project proposals for experiments to be carried out on the permanent Tiangong space station. The proposals were then evaluated by a team of experts from the United Nations Office for Outer Space Affairs (UNOOSA), the CMSA and the international space community. On 12 June 2019 six experiments were accepted, with a further three conditionally selected.

The experiments chosen represent a global community, as the nine projects involved represent 23 institutions from 17 member states of the United Nations in Asian-Pacific, European, African, North American and South American regions, including private sectors and government organisations, as well as international associations.

China's impressive human spaceflight program has gone from strength to strength as the nation has successfully implemented new technologies and achieved set milestones in a relatively short period of time. The Tiangong modular space station not only represents the significant strength of the nation's space program, but also the power and value of global collaboration with regards to scientific research and understanding.

Above: Control centre staff during the first in-orbit refuelling of Tiangong-2 by the Tianzhou 1 cargo spacecraft

Daisy Dobrijevic
Staff Writer
Daisy is **All About Space**'s Staff Writer. She previously worked for *BBC Factual* as a researcher and *BBC Sky at Night* magazine as an editorial assistant.

COMPARISON OF SPACE STATIONS

INTERNATIONAL SPACE STATION

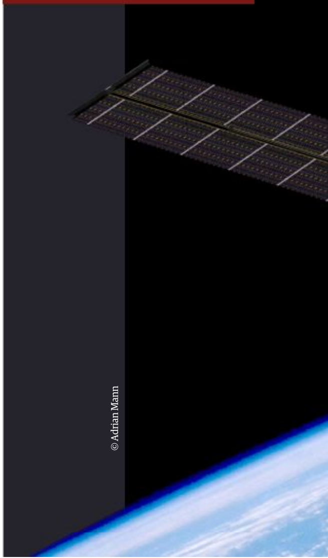
Maximum length: 109 metres (357.6 feet)
Mass: 420 tonnes
Life span: 26 years if deorbited in 2024
Crew size: Six normally, or nine short-term
Initial launch date: 1998

CHINESE SPACE STATION

Maximum length: 37 metres (121.4 feet)
Mass: 90 tonnes
Life span: Ten years or more
Crew size: Three normally, or six short-term
Initial launch date: 2021

MIR

Maximum length: 31 metres (101.7 feet)
Mass: 130 tonnes
Life span: 15 years
Crew size: Three normally, or six short-term
Initial launch date: 1986



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ON BOARD THE MODULAR STATION

1 TIANHE CORE MODULE AND LIVING QUARTERS

The core module of the space station, Tianhe will house the main living quarters for crews of three taikonauts during visits up to six months at a time.

2 TIANHE DOCKING HUB

Tianhe will house a docking hub to allow for the joining of experimental modules, visiting Tianzhou cargo vessels and crewed Shenzhou spacecraft.

3 WENTIAN

This module will be primarily used for scientific research, as well as acting as a working and living space during an emergency. Wentian can also be used to control aspects of the space station relating to propulsion and orientation should there be an issue with Tianhe.

4 MENGTIAN

Similar to Wentian, both modules possess an air lock chamber to support extravehicular activities, as well as a small mechanical arm to aid installation and operation of extravehicular instruments.

5 MANOEUVRABLE SOLAR ARRAYS

The solar arrays will provide electrical power to the space station. When the space station passes into Earth's shadow, stored energy is used to power the space station.

6 TIANZHOU CARGO SHIP

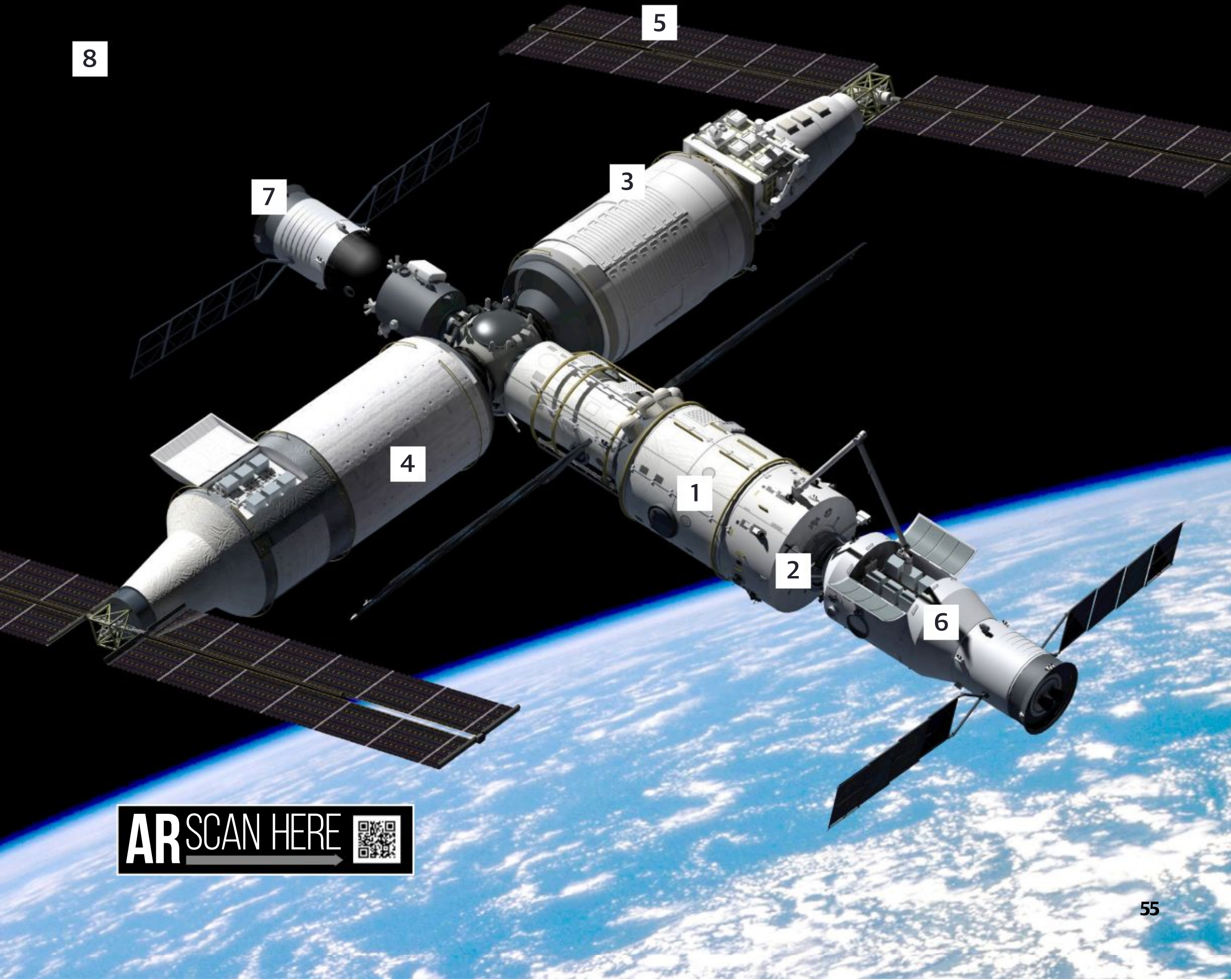
This cargo freighter will resupply the space station with fuel and essentials. It will act in a similar fashion to Russia's Progress or SpaceX's Cargo Dragon capsule.

7 SHENZHOU SPACECRAFT

This spacecraft – similar in design to Russia's Soyuz capsule – will ferry taikonauts to and from the space station. It has been used in previous missions to space labs Tiangong-1 and 2.

8 XUNTIAN SPACE TELESCOPE

Currently under construction is an ambitious telescope with a proposed lens two metres (6.6 feet) in diameter. Xuntian will have a field of view 300 times larger than that of Hubble. Xuntian will be placed into orbit close to the space station so it can dock for repairs and upgrades.



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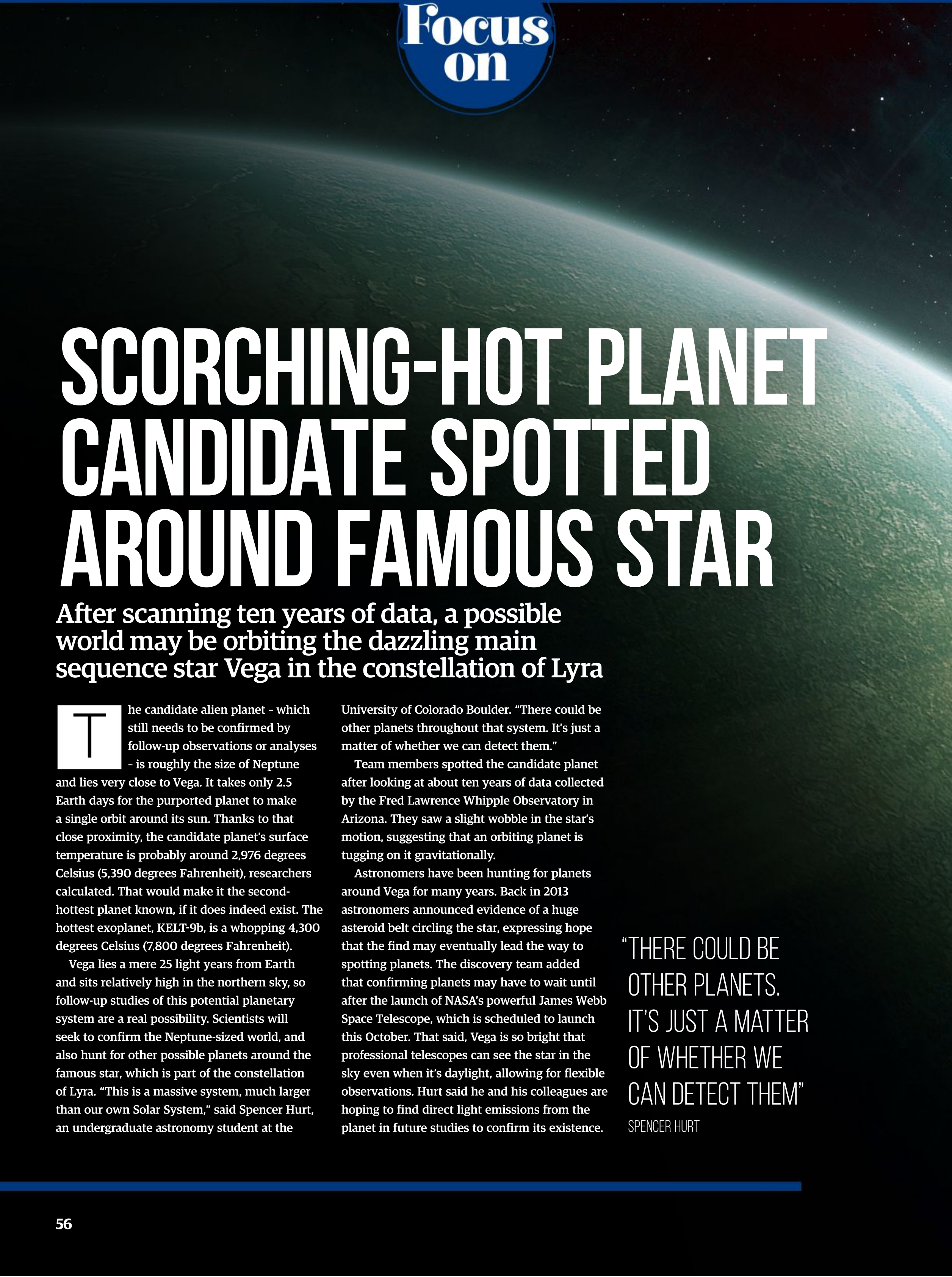

SCORCHING-HOT PLANET CANDIDATE SPOTTED AROUND FAMOUS STAR

After scanning ten years of data, a possible world may be orbiting the dazzling main sequence star Vega in the constellation of Lyra

The candidate alien planet – which still needs to be confirmed by follow-up observations or analyses – is roughly the size of Neptune and lies very close to Vega. It takes only 2.5 Earth days for the purported planet to make a single orbit around its sun. Thanks to that close proximity, the candidate planet's surface temperature is probably around 2,976 degrees Celsius (5,390 degrees Fahrenheit), researchers calculated. That would make it the second-hottest planet known, if it does indeed exist. The hottest exoplanet, KELT-9b, is a whopping 4,300 degrees Celsius (7,800 degrees Fahrenheit).

Vega lies a mere 25 light years from Earth and sits relatively high in the northern sky, so follow-up studies of this potential planetary system are a real possibility. Scientists will seek to confirm the Neptune-sized world, and also hunt for other possible planets around the famous star, which is part of the constellation of Lyra. "This is a massive system, much larger than our own Solar System," said Spencer Hurt, an undergraduate astronomy student at the University of Colorado Boulder. "There could be other planets throughout that system. It's just a matter of whether we can detect them."

Team members spotted the candidate planet after looking at about ten years of data collected by the Fred Lawrence Whipple Observatory in Arizona. They saw a slight wobble in the star's motion, suggesting that an orbiting planet is tugging on it gravitationally.

Astronomers have been hunting for planets around Vega for many years. Back in 2013 astronomers announced evidence of a huge asteroid belt circling the star, expressing hope that the find may eventually lead the way to spotting planets. The discovery team added that confirming planets may have to wait until after the launch of NASA's powerful James Webb Space Telescope, which is scheduled to launch this October. That said, Vega is so bright that professional telescopes can see the star in the sky even when it's daylight, allowing for flexible observations. Hurt said he and his colleagues are hoping to find direct light emissions from the planet in future studies to confirm its existence.

> "THERE COULD BE OTHER PLANETS. IT'S JUST A MATTER OF WHETHER WE CAN DETECT THEM"
>
> SPENCER HURT

Main: Though unconfirmed, there's strong evidence for a planet in orbit

© Getty

WONDERS OF THE UNIVERSE

OUR SOLAR SYSTEM, THE MILKY WAY AND THE UNIVERSE BEYOND ARE FILLED WITH WONDROUS SIGHTS AND INCREDIBLE OBJECTS. TAKE A JOURNEY THROUGH THEM WITH ALL ABOUT SPACE

Written by Nikole Robinson

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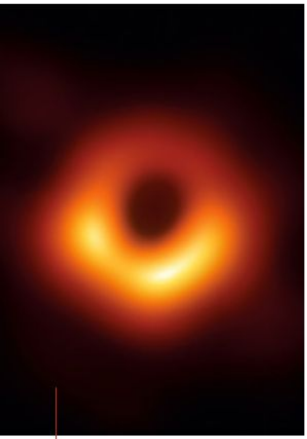
THE DIAMOND PLANET

One of five known planets in orbit around the larger star of a binary pair just 41 light years away from the Sun in the constellation of Cancer, 55 Cancri e is a super-Earth with a speedy orbital period of just 18 hours. As the planet closest to its host star, pressures and temperatures are high, and it is likely tidally locked to its parent body, meaning the same side is constantly facing it.

Studies revealed that the planet has a mass about eight times that of Earth, and a radius twice as wide. Indirect analysis of the planet's composition revealed it has a huge abundance of carbon. Scientists posit that the surface of the planet is covered in graphite, which protects a much more interesting layer of pure diamond underneath, with the rare material accounting for about a third of the planet's mass. If this diamond-encrusted theory proves correct, the planet would be worth around $26.9 nonillion (£19.3 nonillion).



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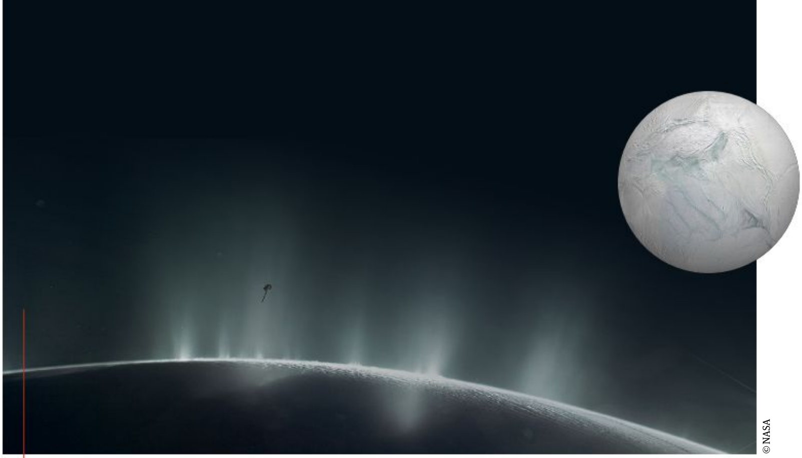
BLACK HOLE REVELATION

Though it's impossible to image a black hole because of their very nature, that didn't stop scientists setting their sights on the supermassive black hole at the centre of Messier 87, a galaxy around 53 million light years from Earth. Using a network of telescopes spanning the entire globe – collectively called the Event Horizon Telescope – combined with a clever computer algorithm, researchers produced this image of the superheated gas swirling around the silhouette of the black hole itself. The captured material appears brighter on one side due to the fact that it is orbiting the massive object – emissions are boosted by the Doppler effect as the material swings towards Earth.

The shadowy object at the centre weighs a whopping 6.5 billion solar masses, while the event horizon – the point at which nothing can escape the gravitational influence of a black hole – spans across 38 billion kilometres (24 billion miles). The first direct image of a black hole lined up perfectly with predictions of how these gargantuan galaxy gobblers might look, and supports Einstein's theory of general relativity.



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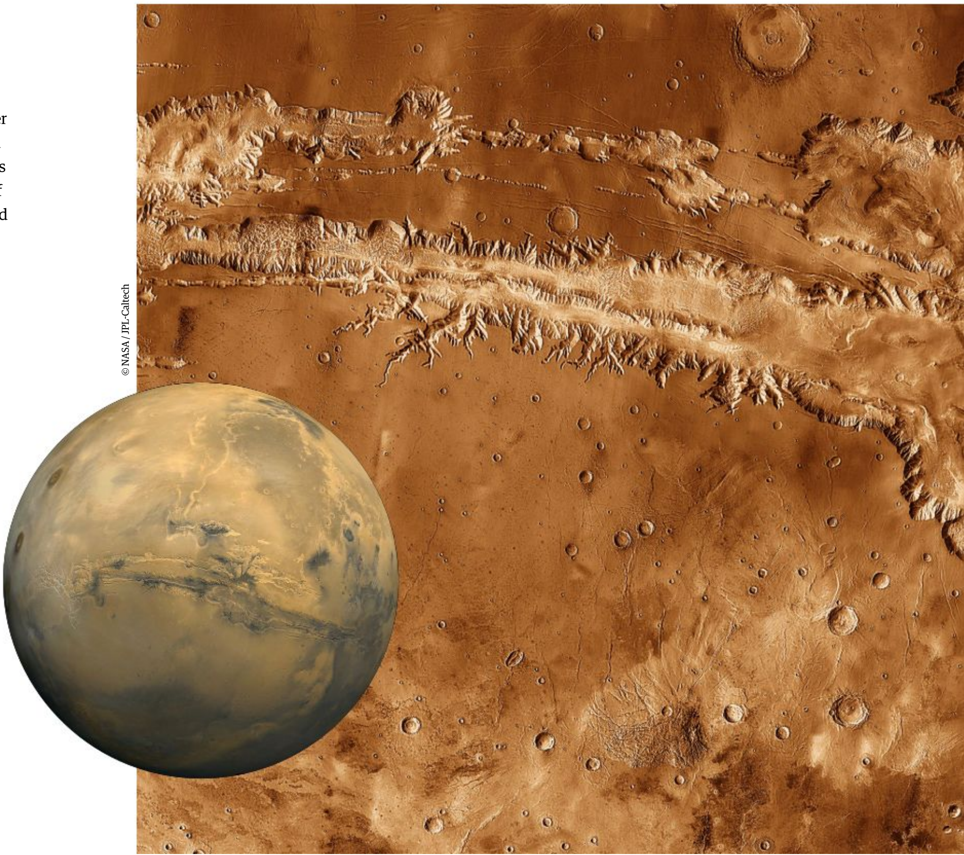
A MOON WITH PLUMES

The Cassini mission to Saturn revealed its sixth-largest moon, Enceladus, to be a much more interesting place than expected – and also one of the best places in the Solar System to search for life. Perhaps most intriguing is the eruption of geyser-like plumes from the moon's south polar region, spewing water vapour and ice particles from a salty subsurface ocean ten kilometres (six miles) deep, trapped below the icy surface. Cassini flew through the plumes seven times over its 13-year mission. Analyses of the plume material found frozen salt water, methane, heavy organic molecules containing carbon and hydrogen and silicon-bearing grains. It's believed the material ejected in the plumes is responsible for both replenishing the moon's bright surface and contributing material to Saturn's E ring, in which the moon orbits.



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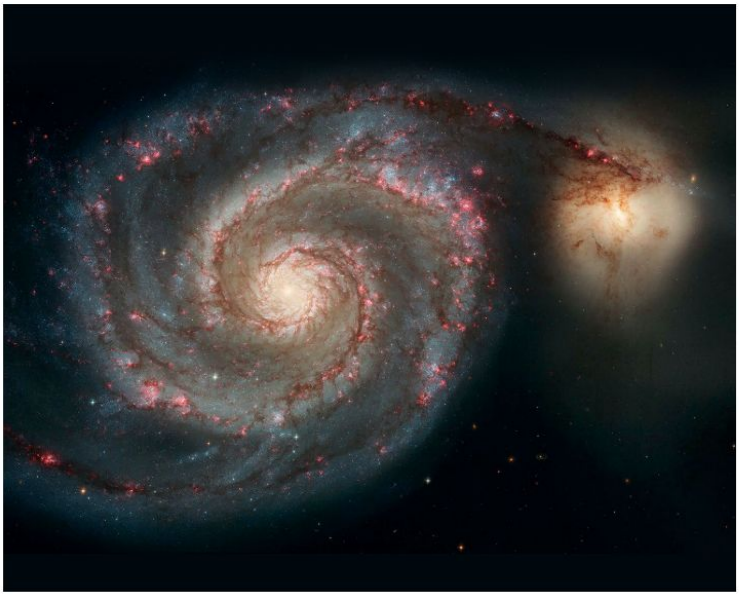

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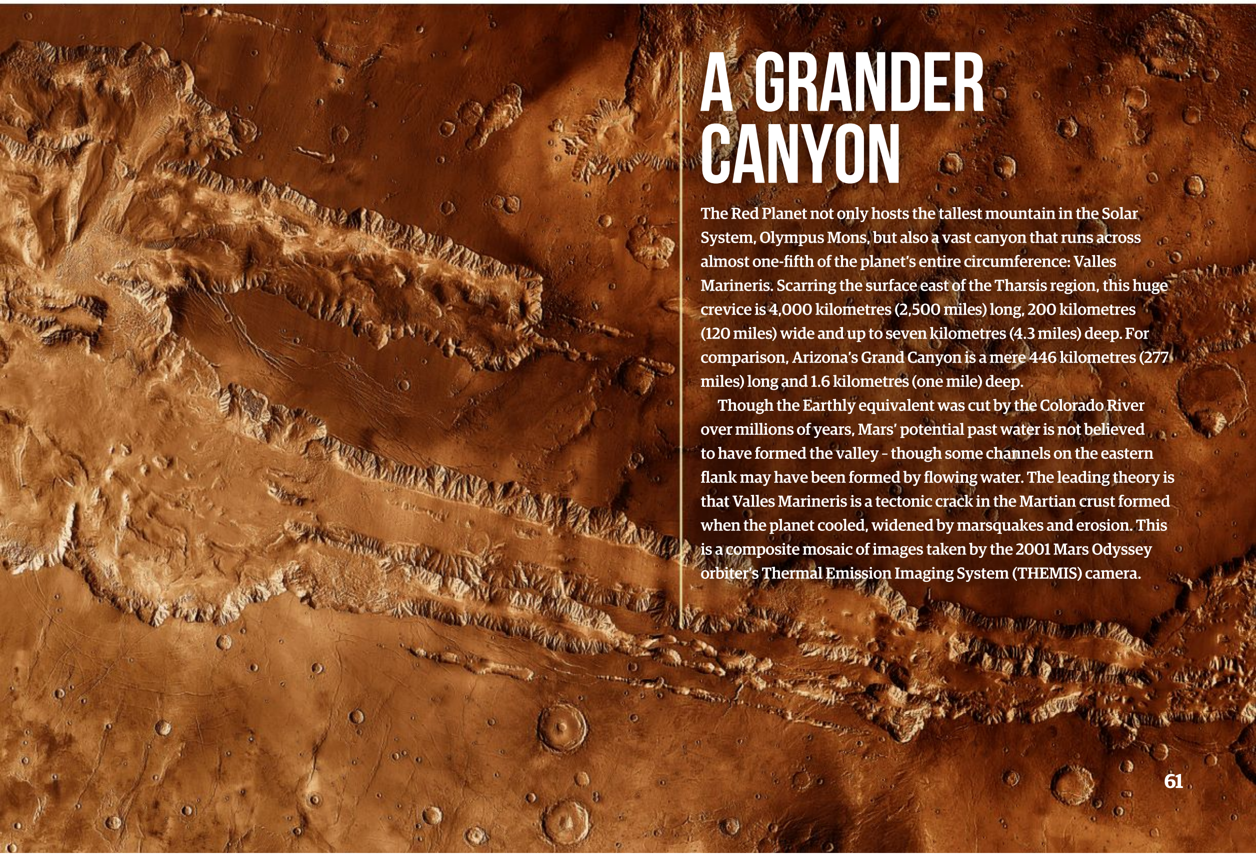
SUCKED INTO THE WHIRLPOOL

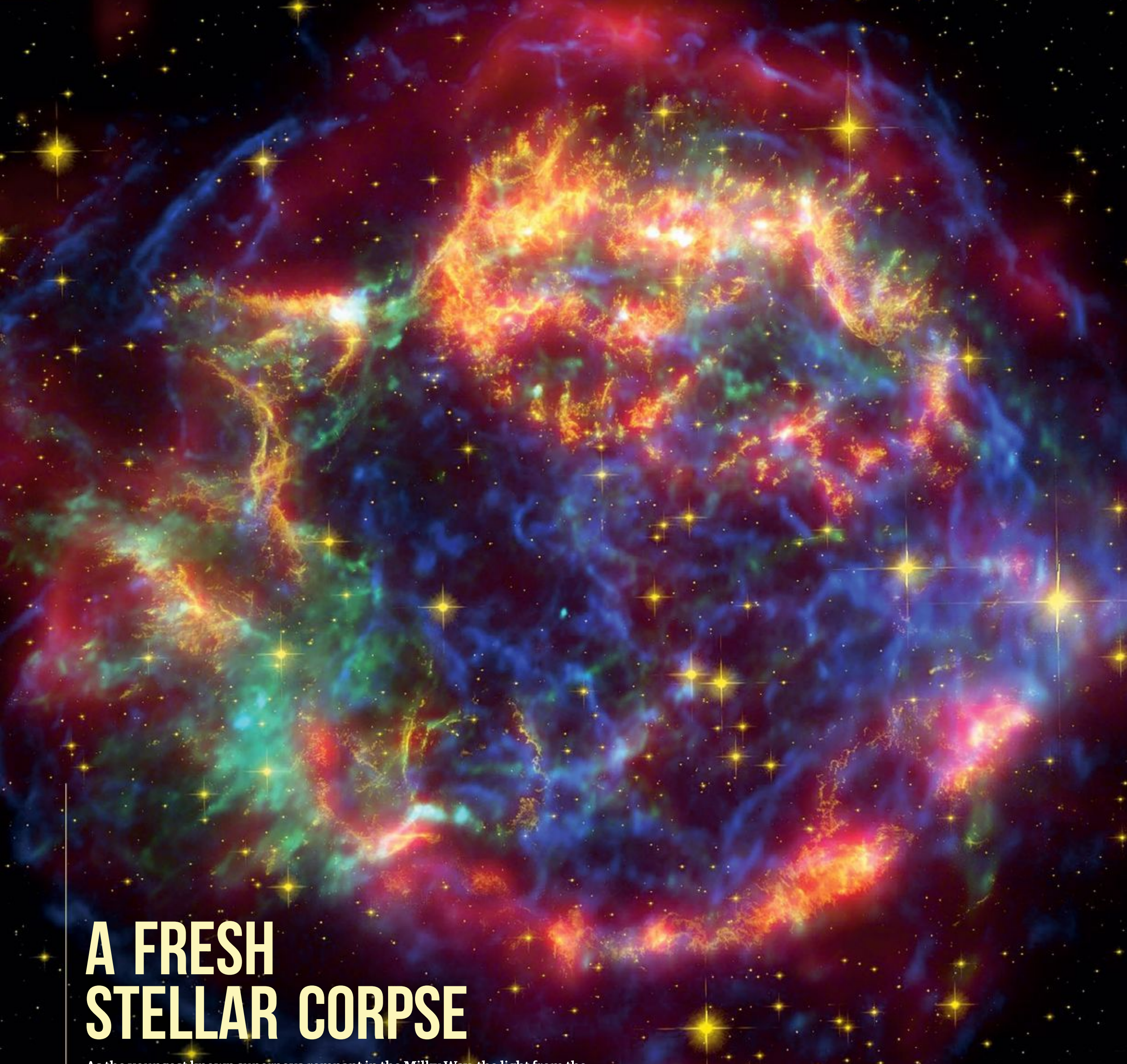
The Whirlpool Galaxy is a popular target for amateur astronomers in Canes Venatici. Although this striking spiral is interesting enough on its own, it is currently in the process of absorbing its dwarf companion NGC 5195, the yellowish object seemingly clinging to one of the Whirlpool's arms on the right. The smaller galaxy has been on a collision course with its neighbour for half a billion years, and currently lies behind it as seen from Earth, evident by the star bridge that links the pair blocking some of its light. In this Hubble image of the pair, red highlights the hydrogen within star-forming regions, blue marks hot, young stars while the yellow shows older stars.



A GRANDER CANYON

The Red Planet not only hosts the tallest mountain in the Solar System, Olympus Mons, but also a vast canyon that runs across almost one-fifth of the planet's entire circumference: Valles Marineris. Scarring the surface east of the Tharsis region, this huge crevice is 4,000 kilometres (2,500 miles) long, 200 kilometres (120 miles) wide and up to seven kilometres (4.3 miles) deep. For comparison, Arizona's Grand Canyon is a mere 446 kilometres (277 miles) long and 1.6 kilometres (one mile) deep.

Though the Earthly equivalent was cut by the Colorado River over millions of years, Mars' potential past water is not believed to have formed the valley – though some channels on the eastern flank may have been formed by flowing water. The leading theory is that Valles Marineris is a tectonic crack in the Martian crust formed when the planet cooled, widened by marsquakes and erosion. This is a composite mosaic of images taken by the 2001 Mars Odyssey orbiter's Thermal Emission Imaging System (THEMIS) camera.



A FRESH STELLAR CORPSE

As the youngest known supernova remnant in the Milky Way, the light from the explosion is thought to have first reached Earth in the 1600s, though there are no observational records to confirm the exact date. Lying 11,000 light years away, the star exploded many years before the light reached us, ripping itself apart and spreading material back into space. This material contains heavier elements than those found in living stars, and will one day form new stars – and potentially planets in orbit around them – with more complex chemistry.

This image compiles data from three observatories to show an immense amount of detail: infrared data from the Spitzer Space Telescope is seen in red hues, visible data from Hubble provides the gold and data from the Chandra X-ray Observatory adds the blues and greens. The tiny bright-blue speck just away from the centre is all that remains of the star's core after the expulsion of material.

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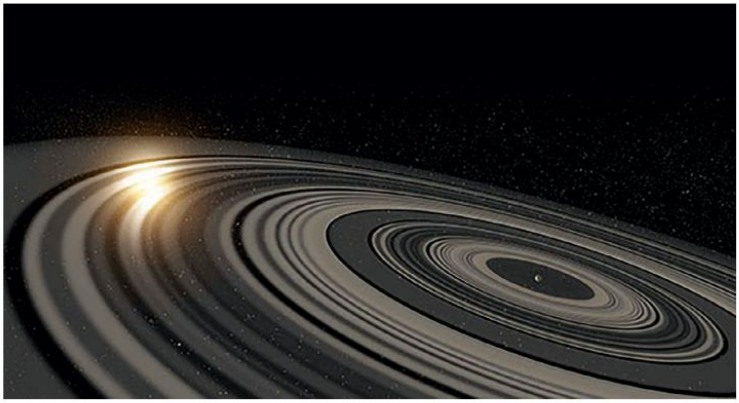

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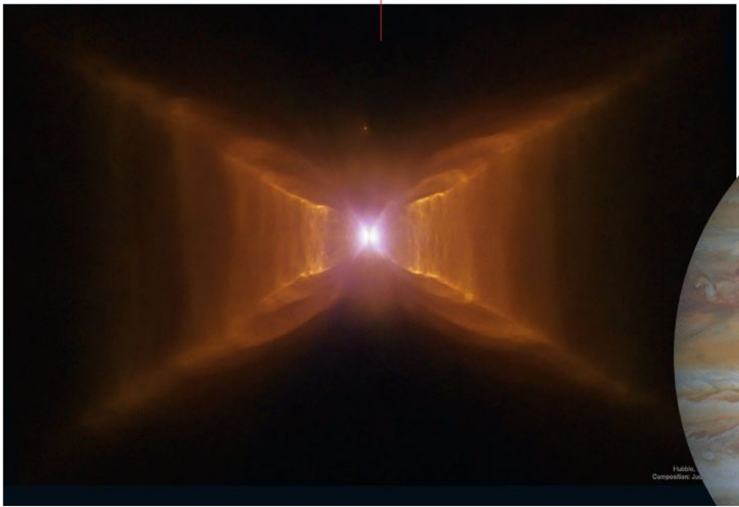
SUPER SATURN

Saturn is well known for its vast system of rings, composed of icy and rocky material. In 2012 the first detection of an exoplanet supporting a similar ring system was made using the transit method when the bands encircling the potential planet, dubbed J1407b, eclipsed their Sun-like host star for several days – and later studies have shown that this system of rings is far more expansive than Saturn's.

Consisting of at least 30 separate rings, the system has a diameter of almost 120 million kilometres (74.5 million miles), 200 times that of the Saturnian system. J1407b is likely a giant planet with a mass of between 13 and 26 Jupiter masses, while the particles that make up the ring system have a similar mass to Earth. A gap in the ring system around 61 million kilometres (38 million miles) from the centre highlights the possibility of an exomoon in orbit.

RED RECTANGLE

This unusual, X-shaped protoplanetary nebula radiates from a close binary star system called HD 44179, and was discovered around the pair by an infrared sky survey in 1973. Lying 2,300 light years away in the constellation of Monoceros, it's still unknown what causes the red colour of the nebula, but its shape is thought to be caused by the outflowing of stellar material from the binary pair at the centre as they shed their outer layers in their final stages of life. The cone-like structures on either side show how material is being ejected in two opposing directions. The rung-like features that can be seen vertically crossing the cones on both sides – giving the Red Rectangle Nebula the unique appearance of a spider's web – are evidence of episodes of mass ejection, where an outpouring of material is ejected every few hundred years.



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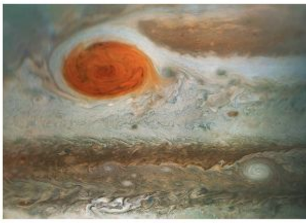

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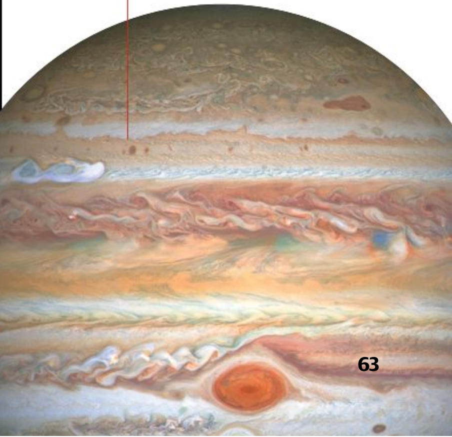
A GIANT RED STORM

The king of the Solar System is covered with tempestuous, caramel-coloured cloud bands, but its most prominent feature is the red, oval-shaped storm known as the Great Red Spot (GRS). Swirling at speeds of up to 432 kilometres (268 miles) per hour between two jet streams in the planet's southern hemisphere, even after sending two probes to orbit the gas giant, scientists still aren't sure what causes the storm's conspicuous colour.

The largest storm in the Solar System, the GRS has been continuously observed since 1879, though it was recorded earlier in 1831. Rotating counterclockwise with a period of around six Earth days, the GRS measured 16,350 kilometres (10,160 miles) across in 2017 – 1.3 times the diameter of Earth – though it appears to be shrinking. NASA's Juno spacecraft captured this close-up of the storm on 1 April 2018 as it made its 12th close flyby of the planet, when the spacecraft skimmed 24,749 to 49,299 kilometres (15,379 to 30,633 miles) above the tops of the Jovian clouds.



STAR PROFILE

Eta Carinae

This star has refused to die, but astronomers are sure it's going to blow up soon

There was a time, about 180 years ago, when Eta Carinae became the second-brightest star in the southern sky. Observed around 1843 in the constellation Carina (the Keel), the supermassive star experienced an enormous celestial outburst, the cause of which has long since been a mystery.

Occurring between 1837 and 1858, the event became known as the Great Eruption, causing the star to become ever brighter until it eventually faded to the point it could no longer be seen by the naked eye. Intriguingly, it released as much visible light as a supernova explosion, but unlike novae and supernovae, the brightness remained for some time. It also didn't die.

Over the years we've come to learn more about Eta Carinae, the star once known as Eta Argus. Having brought us tantalisingly close to a naked-eye witnessing of a supernova within the Milky Way for the first time since 1604, we know that it's a stellar system containing at least two stars.

We also know that it's some 7,500 light years away from the Sun and that it's surrounded by a cloud of dust and gas called the Homunculus Nebula, which was ejected from the star following the outburst in 1843. Astronomers believe it's likely to be the next star in our galaxy to explode as a supernova because it's thought to be approaching the end of its life. If it does, it promises to be some sight.

So when was it originally discovered? There's a bit of a riddle around that too. In 1595 a Dutch navigator called Pieter Keyser made some reasonably accurate observations of the southern stars, and this included a fourth-magnitude star that appeared to match Eta Carinae. The earliest firm recording, however, was made by English astronomer Edmond Halley in 1677, who catalogued the star two years later.

Years later in the 1830s, English astronomer and polymath John Herschel noted a constant shining at a magnitude of 1.4 at its peak. It wasn't until 2005 that NASA's Far Ultraviolet Spectroscopic Explorer satellite detected the companion star for the first time. This followed a sudden doubling of brightness in 1998 and 1999, which had once again allowed the star to be seen with the naked eye.

Now known to be a binary system, there's Eta Carinae A – a luminous, blue variable because of its unpredictability – and Eta Carinae B, a massive, luminous, hot star, and both are estimated to be about 3 million years old. Their eccentric orbits bring them close every 5.54 years.

Astronomers know this because there's a repeating pattern of changes in visible, X-ray, radio and infrared light. It's at the 5.54-year interval that the X-rays vanish for three months – the time when Eta Carinae A eclipses a region at which X-rays are generated when the powerful stellar winds produced by both stars collide.

But even that's not the full story. In 1887 Eta Carinae erupted again, peaking at magnitude +6.2 five years later, yet still it survives. For how much longer is anyone's guess, although it ensures that astronomers will continue to monitor and study this star for many more years to come.

© ESO

Left: The Carina Nebula can be seen as the brightest star to the left of the image

“ASTRONOMERS BELIEVE IT’S LIKELY TO BE THE NEXT STAR IN OUR GALAXY TO EXPLODE”

ATMOSPHERIC COMPOSITION

60%
HYDROGEN

40%
HELIUM

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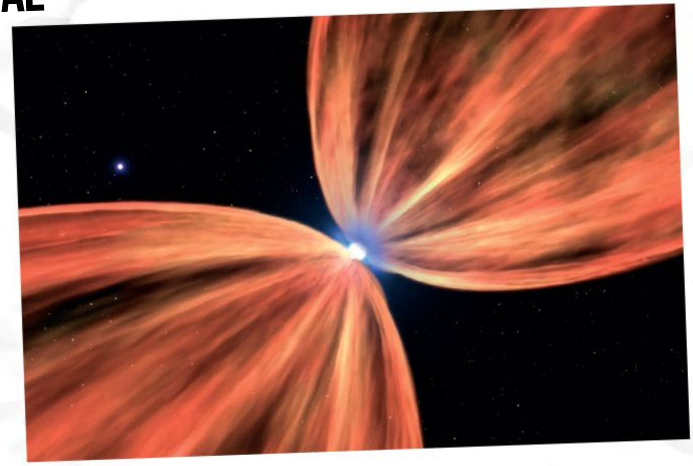
NEWS FROM ETA CARINAE

Why didn't the star die?

Even though the blast from Eta Carinae resulted in as much energy being unleashed as a supernova, the fact the star didn't perish has interested astronomers, leading to much research. In 2018, two studies looked at the light which rebounded off interstellar dust as it made its way to Earth. This is called a light echo, and the delay when compared to the light taking a direct route allows experiments to be conducted many decades later. Astronomers at the University of Arizona's Steward Observatory and Armin Rest of the Space Telescope Science Institute in Baltimore, Maryland, found that the eruption in the 1840s may have been due to a three-way fight. Papers suggest there were three stars, and that Eta Carinae gobbled one of them up when the system became unstable, sending more than ten times the mass of our Sun into space. It's perhaps why the star system looks like two bipolar lobes today. What was surprising, however, was the speed at which the material expanded. The studies suggest it was 20 times faster than expected, putting it on par with supernovae explosions.



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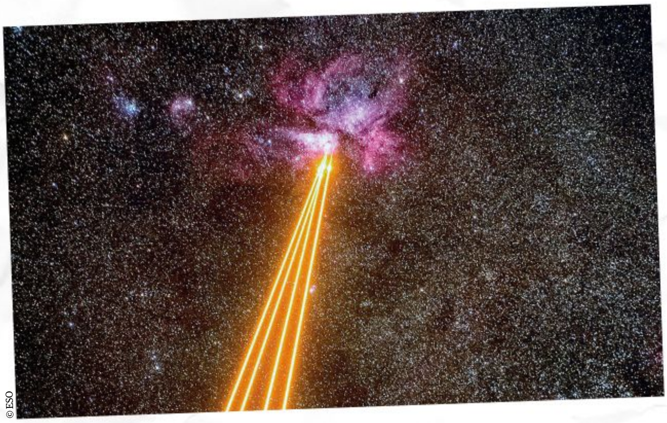

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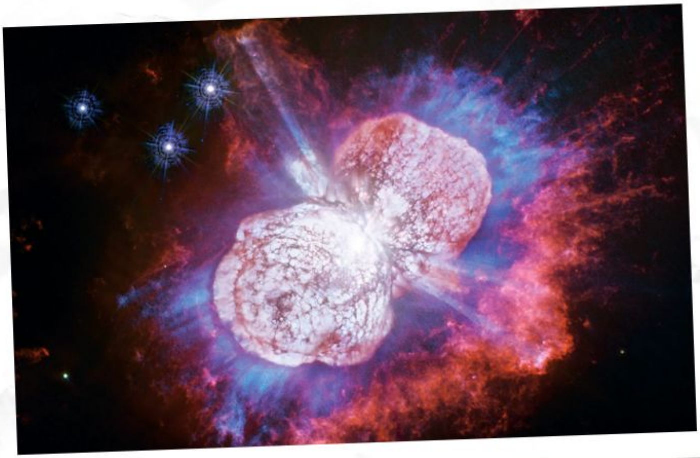
Blasting it with lasers

It's like something from a science-fiction film, but these four orange laser beams are serving a very real purpose: helping astronomers measure the blurring effects caused by Earth's atmosphere. Since our planet's gassy atmosphere blurs and distorts the view of celestial objects, scientists have turned to this method, which enables corrections to be made on the telescope, ensuring it's easier to accurately study and explore such faraway objects. Here the beams are being sent into the atmosphere towards the Carina Nebula from the Adaptive Optics Facility installed on one of the four 8.2-metre Unit Telescopes of the European Southern Observatory's Very Large Telescope in Chile. The nebula is a stellar nursery of gas and dust that surrounds the star system. The glow you can see is caused by the beams exciting sodium particles. The reason the nebula is pink is because the stars are shining through its ionised cloud of dust and gas. The technique results in more pin-sharp images being taken.

Uncovering intricate details

In 2019, Eta Carinae was captured by Hubble in a new level of detail, and Hubble made a surprising discovery. Although Hubble has monitored the star system for more than two decades, astronomers used the Wide Field Camera 3 to map the ultraviolet glow of magnesium embedded in warm gas. They expected the red areas of shocked nitrogen gas in the image to have been interspersed with blue-coloured light from the magnesium. But what they discovered was an abundance of magnesium in the gap between the two giant expanding bubbles and the outer layer. "We've discovered a large amount of warm gas that was ejected in the Great Eruption but hasn't yet collided with the other material surrounding Eta Carinae," explained Nathan Smith of Steward Observatory at the University of Arizona in Tucson, lead investigator of the Hubble program. "Most of the emission is located where we expected to find an empty cavity. This extra material is fast, and it 'ups the ante' in terms of the total energy for an already powerful stellar blast."



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FUTURE EXPLORATION OF ETA CARINAE

There's not much chance of humans ever sending a spacecraft to Eta Carinae. It's 7,500 light years away, after all, so it'll take a while for anyone to get there even if we somehow crack travel at the speed of light. This means astronomers are going to have to continue to monitor and study the star system from Earth, but that doesn't mean we are settling for second best and that further breakthroughs are unlikely to happen. It's quite the opposite, in fact. There have been many groundbreaking studies in just the past few years, and these have been shedding fresh light on Eta Carinae – quite literally in some cases.

The Hubble Space Telescope will certainly be keeping its beady eye on things for a while yet, while the NuSTAR space telescope may also potentially be able to give us more clues: in 2018 it found that the star system was accelerating cosmic ray particles to high energies at speeds comparable to light, for instance.

But what of newer telescopes? The James Webb Space Telescope is due to launch in October, and it will study infrared light from celestial objects. It will do so with greater clarity and sensitivity than telescopes today, and there are already plans to direct the telescope in the direction of Eta Carinae. The star system's pillars of dust can be clearly seen in infrared light, so more information will surely be ascertained in the years ahead. Astronomers will also benefit from other telescopes, such as the Giant Magellan Telescope, the Square Kilometre Array and the Extremely Large Telescope. These will prove essential for the studying of star systems and allow for a level of detail that could only be dreamed of not too long ago.

Below: The primary mirror segment of the James Webb Space Telescope being inspected

© NASA

ETA CARINAE BY NUMBERS

5,000,000
times the brightness of our Sun for Eta Carinae A

1843
The year the Homunculus Nebula came into existence

100
solar masses. The mass of the primary star compared to 30 for the secondary.

6,200,000
MILES PER HOUR
Speed at which the stellar winds of both suns collide

Eta Carinae is the only known star to produce a gas cloud that acts like natural ultraviolet laser emissions

3,000,000
Estimated age, in years, of the star system

35,000
DEGREES CELSIUS
The temperature of the primary star at its highest

THE EVOLUTION OF ETA CARINAE

Age: 0 years
Activity: As with any star, Eta Carinae formed when the clouds of gas and dust scattered in the Milky Way accumulated, then collapsed due to gravity.

Age: 290,000 years
Activity: At this point Eta Carinae was a protostar, having accreted more mass over time. There is a theory that all stars are born with a twin, or even a third sibling.

Age: 3 million years
Activity: The stars of Eta Carinae fused hydrogen to form helium, and the energy that was released caused them to shine bright.

Date: 1837
Activity: About 180 years ago, the star is observed to have erupted with such ferocity that it became the second-brightest star in the sky.

Date: 1887
Activity: After that Great Eruption, there was a Lesser Eruption, observed in 1887 and reaching sixth magnitude five years on. It also brightened on further occasions.

Date: Today
Activity: Eta Carinae remains an unstable, volatile star that is likely to explode at some point in a powerful blast called a supernova – but there's still time to observe it.

Date: Future
Activity: Who knows when it will finally die, but one thing's for sure, rumours that it will cause a mass extinction on Earth are wide off the mark.

MYSTERIES OF THE UNIVERSE

IS THERE A PLANET NINE?

Mike Brown is the man who killed Pluto, but have the tables turned to leave his own theory of a ninth world in doubt?

Reported by David Crookes

© Tobias Roetsch

Mike Brown is a professor of planetary astronomy at the California Institute of Technology (Caltech), but he is also known as the 'Pluto killer'. It was 2006 when the International Astronomical Union downgraded Pluto's planetary status to that of a dwarf. Brown led the charge following his discovery of Eris in January the previous year, and it meant the Solar System was back to having just eight planets. For some, the move was unthinkable. Dr Alan Stern, who headed up the New Horizons mission that sent a spacecraft to Pluto, was particularly angry. Yet it had been coming since 1992, when a new object was discovered in what became known as the Kuiper Belt beyond the orbit of Neptune.

What few saw coming, however, was the emergence of a new candidate for the ninth planet. As if to rub salt in the wounds of those who felt Pluto's status should be reinstated, it was Brown – along with a fellow professor of planetary science at Caltech, Konstantin Batygin – who put the theory forward ten years later based on observations of six extreme trans-Neptunian objects, or ETNOs.

One of them, Sedna, is 40 per cent the size of Pluto, and it behaves in an odd way. Rather than forming an elliptical ring around the Sun as expected, this large planetoid in the outer reaches of the Solar System – some three-times farther away than Neptune – has an exceptionally long and elongated orbit. Taking about 11,400 years to complete its orbit, it will at some point be 76 astronomical units (AU) from the centre of our Solar System – that's 76 times the distance between Earth and the Sun – but it will swing out to more than 900 AU.

What's more, it's not alone. Brown and Batygin observed a cluster of six other ETNOs with similar orbits, and they tilt on their axis in the same direction. They don't appear to be as affected by the known giant planets in our Solar System as other trans-Neptunian objects, so the two scientists came up with an explanation.

According to Brown and Batygin's calculations and modelling, the unexpected clustering of objects is due to the gravitational pull of an as-yet-undiscovered ninth planet that is between 13 and 26 times farther out than Neptune. This hypothetical celestial body would have a predicted mass between five and ten times that of Earth. Its orbit would be elongated, ranging between 400 and 800 AU.

It's an exciting proposition, yet one that has not gone unchallenged. A study led by Kevin Napier at the University of Michigan has cast doubt on the theory. By observing 14 far-off rocky bodies discovered by three surveys – five each from the Dark Energy Survey and the Outer Solar System Origins Survey and a further four picked up by astronomers Scott Sheppard, Chad Trujillo and David Tholen – they say there is no

"IT WOULD HAVE BEEN MORE EXCITING IF OUR FINDINGS SHOWED STRONG EVIDENCE FOR CLUSTERING, AND THUS FOR PLANET NINE" KEVIN NAPIER

PLANET NINE
BY THE NUMBERS

5-10
times the mass of Earth

2-4
times the radius of Earth

400-800
times farther from the Sun than Earth

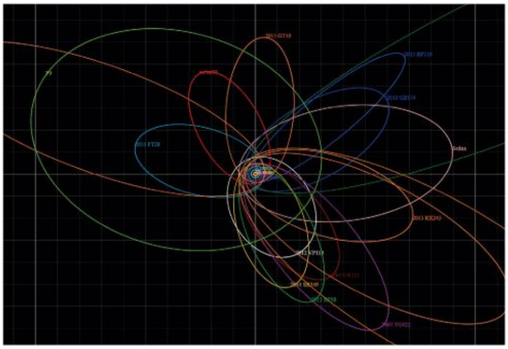
0
Number of observations

6
Number of extreme trans-Neptunian objects which appear affected by Planet Nine

10,000-20,000
Years to make a full orbit of the Sun

20 YEARS
Time Mike Brown estimates it would take for a probe to reach the planet

0.2-0.5
The hypothesised eccentricity of Planet Nine's orbit



Source: Wikipedia Commons © Tomruen

Top: An artist's concept of Planet Nine in orbit far from the Sun

Above: The original six ETNOs used by Brown and Batylin to hypothesise about Planet Nine, along with the planet's theorised orbit (in green) and eight other ETNOs

evidence of ETNO clustering that would firmly indicate the existence of an extra planet.

Instead, they say the findings by Brown and Batygin are due to observational bias. In other words, the new research reckons that Planet Nine's apparent existence is mainly based on the direction in which the two scientists' telescopes looked. Since Brown and Batygin observed just a small section of sky, the selection of ETNOs was limited. This, says Napier, weakens the case.

"Simulations have shown that Planet Nine causes the orientations of the ETNOs' orbits to cluster on timescales comparable to the age of our Solar System," Napier explains to **All About Space**. "There are now on the order of a dozen known ETNOs that appear to exhibit this clustering, and if you look at the data, the clustering appears to be rather robust.

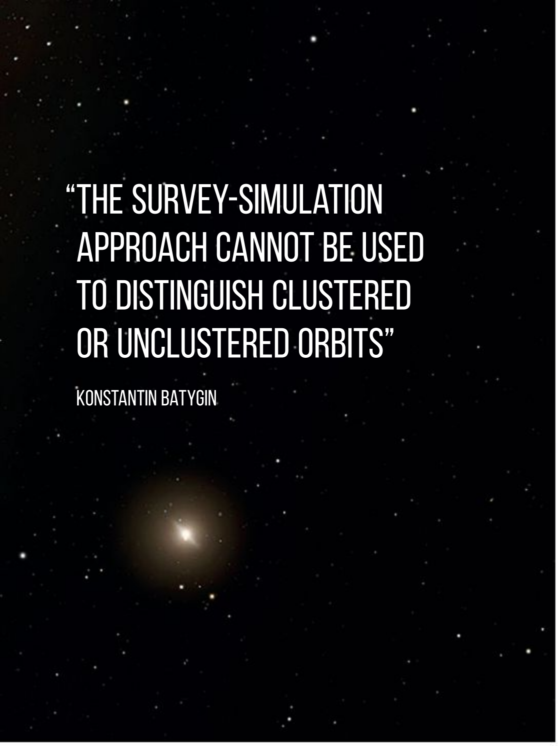
"But you cannot simply look at the data and draw robust conclusions because of this effect called observational bias. It takes into account factors such as where you pointed the telescope, when you took the observation and how faint of an object the telescope was able to see.

"Because the ETNOs are on exceptionally long, skinny orbits, they can only be seen for a very short segment, when they are closest to the Sun. This makes the observational biases present in their discovery rather severe. Until our study, nobody had performed a meta-analysis on all of the ETNOs discovered by surveys with calculable biases. It turns out that when you properly account for these observational biases, the population of ETNOs we observe is fully consistent with a uniform - rather than a clustered - underlying distribution."

In carrying out their research, Napier and his team decided to look at ETNOs that were not studied by Brown and Batygin. Those original six were discovered by surveys with unknown biases, "so we were unable to properly analyse them," explains Napier. "We wanted to test an independent sample because in a larger, better controlled sample, you would expect the significance of the clustering to either stay the same or to increase. We found the significance decreased."

Napier's team did include two of the original six objects after their main analysis, however, giving them a total of 16. "We still found that the observations were consistent with a uniform underlying distribution," he adds. But does that mean talk of a Planet Nine is off the table?

Causing some confusion about the conclusion is the title of Napier's academic paper, entitled: No Evidence for Orbital Clustering in the Extreme Trans-Neptunian Objects. It jars with the content of the work itself, and Batygin has not been slow



> “THE SURVEY-SIMULATION APPROACH CANNOT BE USED TO DISTINGUISH CLUSTERED OR UNCLUSTERED ORBITS”
>
> KONSTANTIN BATYGIN

© Caltech

to seize on this. “The Napier et al study does not actually draw the conclusion in the title,” he tells us. “The work demonstrates that the survey-simulation approach cannot be used to distinguish between clustered or unclustered orbits, and this is not particularly surprising. Heavily biased surveys like the Outer Solar System Origins Survey or Dark Energy Survey are very hard to de-bias, and given the limited number of detections in each survey, the fact that survey-simulation cannot rule out any distribution is not perplexing.”

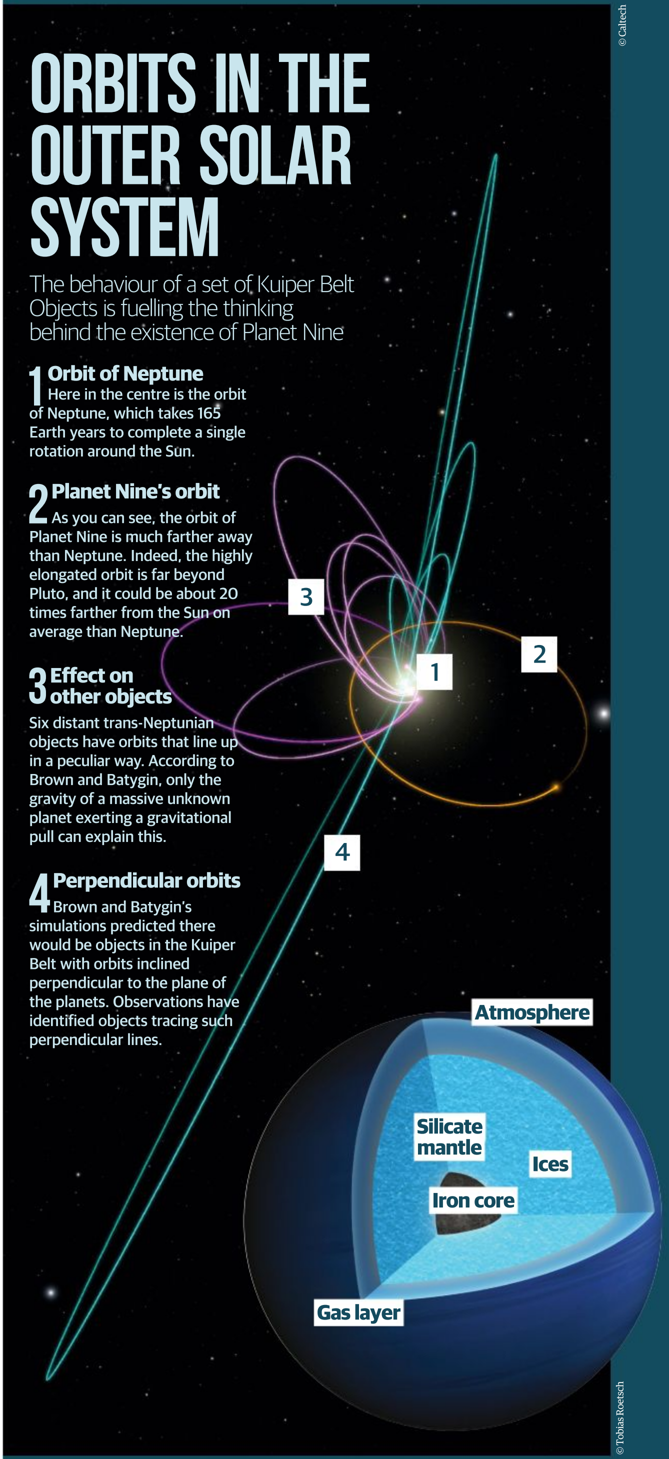
Brown agrees wholeheartedly. “If you read the paper really carefully, then the correct statement from the Napier analysis would be something like: ‘Our survey was very biased, and this could not detect clustering at the level previously detected.’ It’s a big leap that there is no clustering, and it’s one they don’t make in the paper, but do in interviews. In fact, if we add their new objects to our full dataset instead of using their much more limited dataset, the clustering actually improves.”

In our interview, Napier admits that the work doesn’t rule out the existence of Planet Nine, saying only that it has “certainly weakened the case for it”. He says he would have preferred the conclusion to have backed the original hypothesis. “It would have been more exciting if our findings showed strong evidence for clustering in the ETNOs, and thus for Planet Nine,” he says.

“That being said, we still find our results exciting,” he adds. “Even if it turns out that Planet Nine doesn’t exist, there must be some explanation

ORBITS IN THE OUTER SOLAR SYSTEM

The behaviour of a set of Kuiper Belt Objects is fuelling the thinking behind the existence of Planet Nine



1 Orbit of Neptune

Here in the centre is the orbit of Neptune, which takes 165 Earth years to complete a single rotation around the Sun.

2 Planet Nine’s orbit

As you can see, the orbit of Planet Nine is much farther away than Neptune. Indeed, the highly elongated orbit is far beyond Pluto, and it could be about 20 times farther from the Sun on average than Neptune.

3 Effect on other objects

Six distant trans-Neptunian objects have orbits that line up in a peculiar way. According to Brown and Batygin, only the gravity of a massive unknown planet exerting a gravitational pull can explain this.

4 Perpendicular orbits

Brown and Batygin’s simulations predicted there would be objects in the Kuiper Belt with orbits inclined perpendicular to the plane of the planets. Observations have identified objects tracing such perpendicular lines.

© Caltech

© Tobias Roetsch

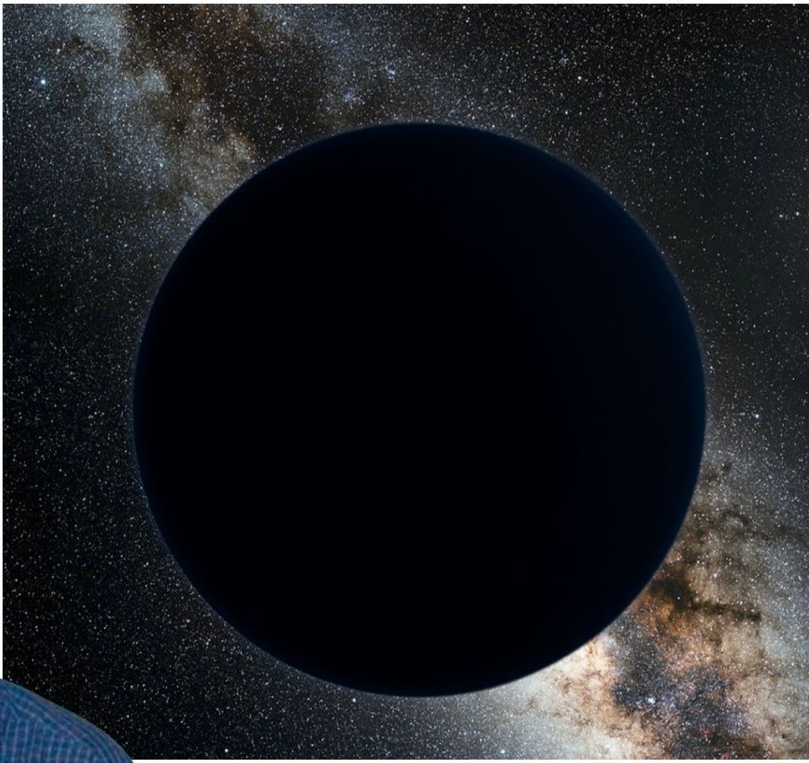
for the orbital behaviour of some of the strangest objects in our Solar System. Examples of such anomalies include Kuiper Belt Objects on highly inclined orbits and objects that never come closer to the Sun than twice the distance of Neptune. Mysteries like this are what keep us going."

As far as Batygin is concerned, the mystery surrounding Planet Nine is still in favour of it being out there somewhere. He says it has been clear for a long time that individual surveys cannot overcome their own biases to rigorously determine clustering one way or another. "In fact, this has already been pointed out multiple times, and the Napier et al analysis combines the well-characterised surveys, but still finds the same answer," he says. "For this reason, in order to determine the 'false-alarm probability' of the clustering, it makes sense to instead do an observability analysis which takes advantage of the full dataset to determine statistical significance." Batygin says he did exactly this in a paper with Brown published in 2019: "The analysis demonstrates that the chances that the data are not clustered is only 0.2 per cent."

By this, Batygin is theorising that the chance of clustering happening naturally without any gravitational pull from a body such as Planet Nine is extremely slim. What's more, as well as the clustering of orbits, the ETNOs with perihelia beyond 50 AU are too sufficiently distanced from Neptune to experience significant gravitational perturbations from it, so it points to something having an effect.

"An important point to understand is that the Planet Nine hypothesis is not just one thing," Batygin says. "There is a collection of lines of evidence that all paint the same picture: clustering of the apsidal lines, grouping of the angular momentum vectors, detached perihelia of long-period Kuiper Belt Objects, excitation of distant Kuiper Belt Objects to high inclinations and generation of the retrograde centaur population of the outer Solar System. The fact Planet Nine ties all these outer Solar System anomalies together gives me some confidence that we are on the right track."

In that sense, he doesn't perceive the study by Napier to have much of an effect on the original hypothesis. "There is one more very important point to understand, which routinely gets lost in translation," he continues. "The distant Kuiper Belt is made up of stable as well as unstable objects, and



Right: An artist's impression of Planet Nine with the Sun in the very far distance, circled by the orbit of Neptune

Below: Brown bears the nickname of 'Pluto killer'

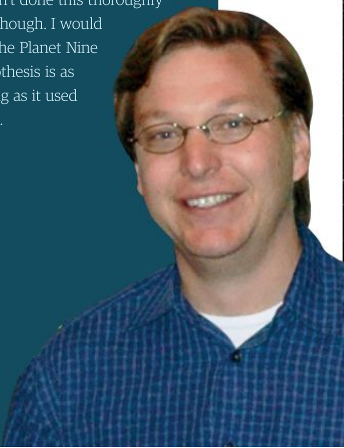
FURTHERING THE CASE FOR PLANET NINE

American astronomer Mike Brown has worked on the hypothesis of another world for the last five years

Some scientists have been unable to create a computer simulation that accounts for the clustered trans-Neptunian objects which form the basis of the theory of Planet Nine. Does this cast doubt over its existence in your mind?
Many groups have reproduced computer simulations that make the Planet Nine cluster. The physics is well understood. It is neither difficult nor mysterious.

Would you say the suggestion that you observed a small portion of the sky during a specific part of the year at a specific time of day is valid?
I haven't heard that suggestion. Our survey is the only one that doesn't do that. The others are much more limited.

How strong is the evidence for a Planet Nine in light of the recent study?
The Napier paper neither adds nor subtracts to the Planet Nine hypothesis, though adding in the new objects would strengthen the hypothesis if we combined it with our full dataset - we haven't done this thoroughly yet, though. I would say the Planet Nine hypothesis is as strong as it used to be.



in the Planet Nine story, it doesn't matter what the unstable objects do.

"If you look at the data, the stable, high-perihelion objects cluster very well, while the unstable objects are all over the place. That's what the theoretical model predicts too. You can imagine a whole range of observational biases that can cause clustering, but it's impossible to bias based on dynamical stability. Because the Napier et al dataset is roughly half stable, it's not a huge surprise they cannot prove that it's clustered." But does that still mean it has to be a planet causing the clustering? With the theory suggesting that gravity is at play, planets are not the only objects able to exert a gravitational pull. Dark matter or a primordial black hole are among the alternative suggestions.

Napier reckons a planet would be the most likely explanation, so long as it's one day proved that the clustering is persistent. "It's hard to imagine it being caused by a dynamical mechanism other than Planet Nine if the clustering is persistent and not transient," he says. But recent work has shown that it's possible we are observing a temporary clustering of the ETNOs. It's clear more work needs to be done.

Certainly, the hypothesis of a Planet Nine is not going away any time soon. "I'm still quite optimistic that Planet Nine exists," says Batygin, with the use of the word 'quite' being notable. Napier, on the other hand, concludes: "I'm hopeful, but not optimistic. It might be there; it might not." Its existence would make life easier, but only one thing would really nail it. "Direct detection would be best," says Batygin, "and the answer to anything short of that is basically more data."

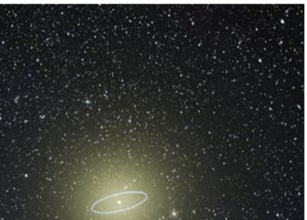
Napier agrees, and both are pinning their hopes on the Vera C. Rubin Observatory in Chile, which is coming online soon. The Legacy Survey of Space and Time at the observatory means the census of trans-Neptunian objects will expand substantially. One of the reasons why sufficient data has been hard to come by so far is access to telescopes and a focus on ETNOs in particular. Estimates are that the survey will discover more ETNOs, and with that data we'll be able to make a compelling statement.

One thing's for sure, there's a willingness for a discovery. In truth, most scientists would love to actually find Planet Nine. "A new planet would be extremely cool, and it would solve a lot of anomalies that we don't understand about our Solar System," Napier says. "But we have to entertain the possibility that there is no Planet Nine and continue searching for alternate explanations of those anomalies." We can only wait with bated breath.

David Crookes

Science and technology journalist

David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.



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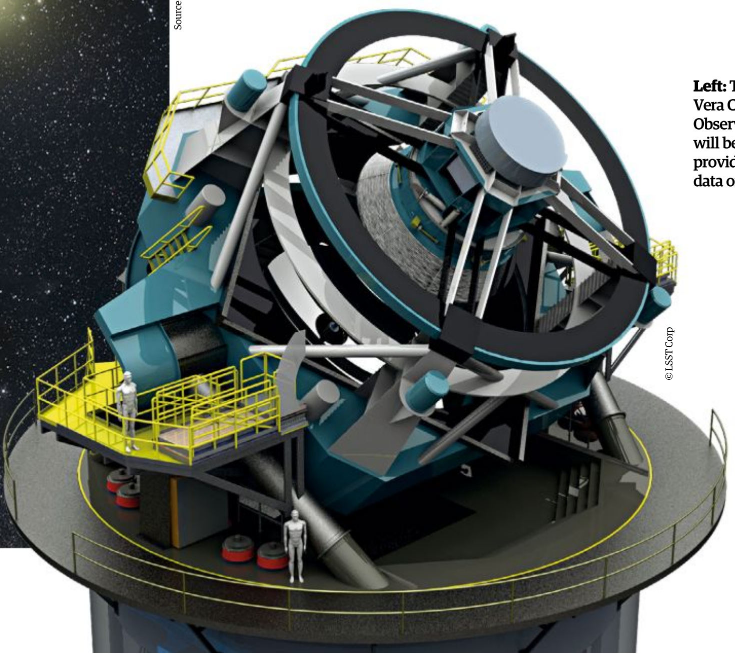

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Left: The Vera C. Rubin Observatory will be able to provide new data on ETNOs

THE THEORIES

What could be affecting the extreme trans-Neptunian objects?

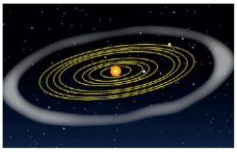
1 Planet Nine

Modelling in 2016 by Brown and Batygin at Caltech hypothesised that six ETNOs had similar orbits because a large planet well beyond Neptune was exerting a massive gravitational pull on them. The scientists are sticking to this theory, and 19 ETNOs are now shown to exhibit a similar tilt and eccentric orbital pattern. This theory has yet to be proved or disproved.

© Getty

2 There's no clustering

According to a recent study headed by Napier, it is possible that there is no clustering in the first place. Other work suggests that any clustering could be temporary, and if either of these are the case then the likelihood of any gravitational pull being exerted is ruled out, thereby leaving any case for a Planet Nine severely dented.



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3 Something else is at play

If the ETNOs are indeed being affected by something in the Solar System, does it have to be a planet? Some scientists are looking into the possibility of a primordial black hole – a black hole which formed soon after the Big Bang – but these are still hypothetical. Dark matter is another potential theory, but again it's one hypothetical explaining another.

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ASK Space

Our experts answer your questions

SOLAR SYSTEM

Will the Moon ever leave us?

Ocean tides driven by the Moon release energy, but that energy has to come from somewhere: the spin of Earth, which must slow down. Physics dictates that the total amount of angular momentum has to stay the same between Earth and the Moon, so the orbit of the Moon has been getting larger for billions of years. But can it ever escape and become its own planet?

If Earth was to spin down completely, the Moon would get to the distance of 87 Earth radii - now it is at 60 Earth radii. Calculations show that orbits closer than about 94 Earth radii are stable, so it looks like the Moon cannot escape, even theoretically. But to actually get to that distance, the Moon may need about 15 billion years, much longer than the 5 billion years Earth has left, in which the Moon likely won't get beyond 75 Earth radii. Also, the Sun's tides steal spin from Earth, reducing what's available to the Moon. Finally, Earth's axial tilt will become chaotic in 1 to 2 billion years, misaligning the axes of Earth's spin and lunar orbit and slowing down tides further. It appears the Moon is here to stay with Earth until its end.

Matija Ćuk, research scientist at the SETI Institute

Below: Artist's impression of the view of Earth from the Moon

© Getty

ASTROPHYSICS

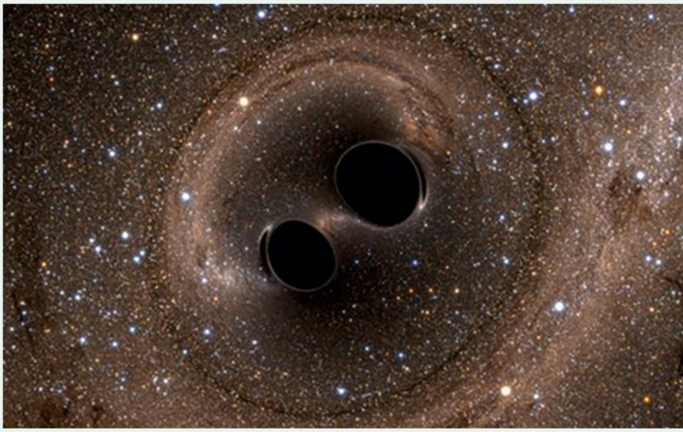
What happens when black holes collide?

Colliding black holes emit a powerful burst of gravitational waves - ripples in the geometry of space-time. Black holes are disconnected regions of the universe, defined by an invisible one-way membrane called the event horizon: you can enter, but never escape. Black holes form when massive stars die; they grow by swallowing up stars, other black holes or interstellar gas.

Like the stars from which they formed, they often live in binary pairs. Over time these binaries get closer, and their orbits strongly perturb space-time, emitting gravitational waves like a moving finger makes waves in a pool. As these waves remove potential energy from the binary, the black holes spiral closer and orbit faster.

Eventually they touch - the event horizons merge like two liquid drops, releasing a final powerful burst of gravitational-wave energy and momentum. A new, more massive black hole remains - but not as massive as the black holes at the start, the mass difference being converted to gravitational-wave energy. Like the sound from a struck bell, the black hole remnant 'rings' away the distortions of its new horizon with a few more waves. The momentum carried away by the waves makes the remnant recoil - like a high-powered rifle - possibly ejecting the new black hole from the star cluster or galaxy where it formed. If not it may sit around for a time, eventually encountering a new, probably lighter black hole, with another collision in its future.

Dr Marc Favata, associate professor at Montclair State University



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Above: The two massive bodies merge into one another, creating ripples in space-time

Did you know?

The discovery of Planet Nine has the potential to completely change measurements of the Solar System's centre.

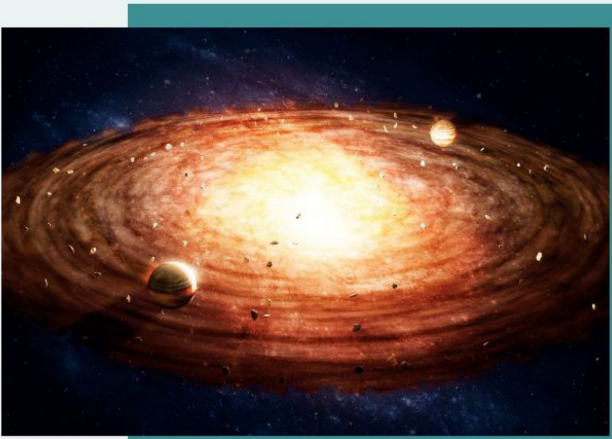
SOLAR SYSTEM

Where is the centre of the Solar System?

One answer considered especially useful by astronomers is the barycentre, the point where the masses of the Sun, the planets and of all bodies in the system balance out. Imagine placing those masses on a huge platform supported by a single pin; now slide the platform until you find the place where it remains perfectly balanced on the pin - that is the barycentre. Now generalise your intuition to three dimensions. The barycentre is important because the equations of gravitation guarantee that it remains still while all bodies move in their orbits.

Because the Sun is so massive, the barycentre lies relatively close to the solar core - in fact, it lies 'inside' the Sun about half of the time. However, the balancing is very sensitive to distant masses: the 2003 discovery of Sedna, the planetoid in the outer reaches of the Solar System, 'moved' the barycentre by more than 16 kilometres (ten miles). Locating the barycentre requires our best knowledge of the masses and orbits of all the planets and their moons, which we obtain with careful astronomical observations and by bouncing radio signals off the spacecraft that we sent cruising through the Solar System.

Michele Vallisneri, astrophysicist at NASA's Jet Propulsion Laboratory in Pasadena, California



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Above: The centre of the Solar System can be found close to the Sun's core

> "BECAUSE THE SUN IS SO MASSIVE, THE BARYCENTRE LIES RELATIVELY CLOSE TO THE SOLAR CORE"
>
> MICHELE VALLISNERI

COSMOLOGY

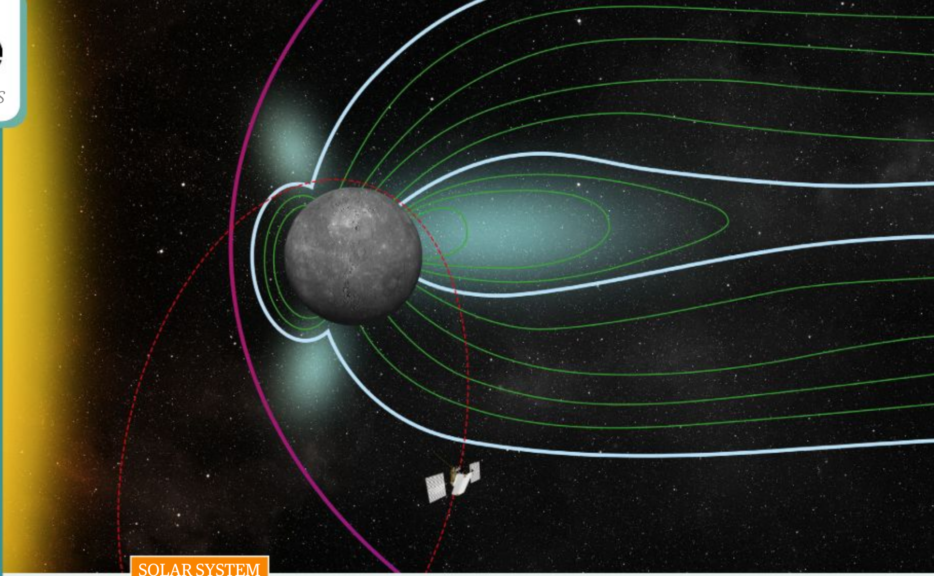
Can a star turn into a planet?

A star can turn into a planet, but only for a particular type of star called a brown dwarf, and only if we use broad definitions of the words 'star' and 'planet'.

A brown dwarf is the lightest type of star, with a mass of about 13 to 80 times the mass of Jupiter. Such a star is too low in mass to trigger the nuclear fusion of regular hydrogen like in normal stars. Instead it triggers the nuclear fusion of heavy hydrogen, which is much rarer. A brown dwarf glows like a normal star, but only dimly.

Over time, a brown dwarf runs out of heavy hydrogen, cools and becomes dark. At this point it can be considered a planet. Despite the fact that it now looks and acts like a planet, a dark brown dwarf continues to sit in the middle of its solar system. Such a solar system therefore becomes a collection of smaller planets orbiting a large, dark, cold central planet. Some scientists define the words 'star' and 'planet' more narrowly, and therefore consider a brown dwarf to be neither star nor planet, but in a class of its own.

Dr Christopher S. Baird, assistant professor of physics, West Texas A&M University



Above: Mercury has a distorted magnetic field due to its proximity to the Sun

Left: Brown dwarfs are considered failed stars

SOLAR SYSTEM

Why don't all planets have magnetic fields?

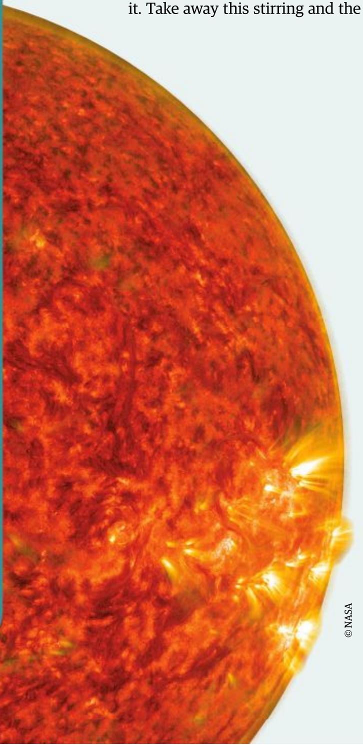
The magnetic field of a planet is generated by fluid motions in an electrically conducting region of its interior. Without such motions, or if they're not vigorous enough, a planet will not have a magnetic field. For Earth this region is the liquid outer core, which is dominantly composed of iron and nickel, and heat escaping the core powers turbulent convective flows.

In a good electrical conductor, magnetic field lines tend to remain attached to material particles, so these flows can twist and shear an existing magnetic field – this is the process that can sustain it. Take away this stirring and the field decays away: for Earth this would take approximately 30,000 years.

The other terrestrial planets have metallic-liquid cores, but only Mercury has a magnetic field. Flows in the liquid cores of Mars and Venus are not vigorous enough, although we know that Mars had a field in the past from the magnetisation recorded in its crustal rocks – and so did the Moon. For the giant planets, the conducting region is metallic hydrogen for Jupiter and Saturn, or ionised water and ammonia for Uranus and Neptune.

© John Ulan

Mathieu Dumberry, associate professor at the University of Alberta



© NASA

ASTROPHYSICS

Could a solar flare wipe out our electronics and satellites?

The energetic particles often associated with solar flares can damage or disrupt satellite operations. Space-based electronics are usually shielded enough to protect them from the energetic X-ray photons from a solar flare, but energetic particles that may also be emitted from the Sun during a solar flare can penetrate into the electronics and create a single-event upset (SEU). Most SEU events can be cleared by power cycling the electronics, but some SEU events can cause permanent damage. These energetic particles of concern are most common with larger solar flares, classified as X-class flares. There is, on average, one X-class flare per month, but there are fewer X-class flares during the 11-year solar cycle minimum period. As of 2021, the Sun is now coming out of its solar minimum period, and its maximum activity period could be in 2024 to 2026.

Tom Woods, principal investigator of the Extreme Ultraviolet Variability Experiment on NASA's Solar Dynamics Observatory

SPACE EXPLORATION

Why are most rockets white?

A white outer colour is useful to minimise heat absorption into the body of the rocket. For rockets that use fuels at very low 'cryogenic' temperatures, such as liquid hydrogen and liquid oxygen, even very small amounts of heat introduction can result in the liquid fuel 'boiling off' into gas and being lost. Europe's Ariane 5 rocket launches from French Guiana in South America, so reducing heat input to the rocket in that hot, tropical climate is important.

However, painting the surface of your rocket white adds weight to the rocket, which you want to be as light as possible, so you only do it when it brings real benefit. You can have rockets which are part white, part another colour, often the natural colour of the structure – orange for the thermal protection of the Space Shuttle fuel tank, for example. You can also decide not to paint the rocket at all – the Electron micro-launcher is all black, the colour of the carbon fibre used in the structure.

Kate Underhill, rocket scientist at the European Space Agency

© ESA

The ESA's Ariane 5 lifts off from Europe's Spaceport in French Guiana

Did you know?

The Russian Soyuz rocket holds the record for most successful launches.

> "PAINTING THE SURFACE ADDS WEIGHT TO THE ROCKET, WHICH YOU WANT TO BE AS LIGHT AS POSSIBLE"
>
> KATE UNDERHILL

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WHAT'S IN THE SKY?

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RED LIGHT FRIENDLY

In order to preserve your night vision, you should read our observing guide under red light

© Alamy

22 APR
The Lyrids reach their peak of 18 meteors per hour

23 APR
Comet C/2020 R4 (ATLAS) will make its closest approach to the Sun at +7.3

4 MAY
Conjunction between the Moon and Jupiter in Aquarius

5 MAY
The Moon and Jupiter make a close approach, passing within 4°21' of each other in Aquarius

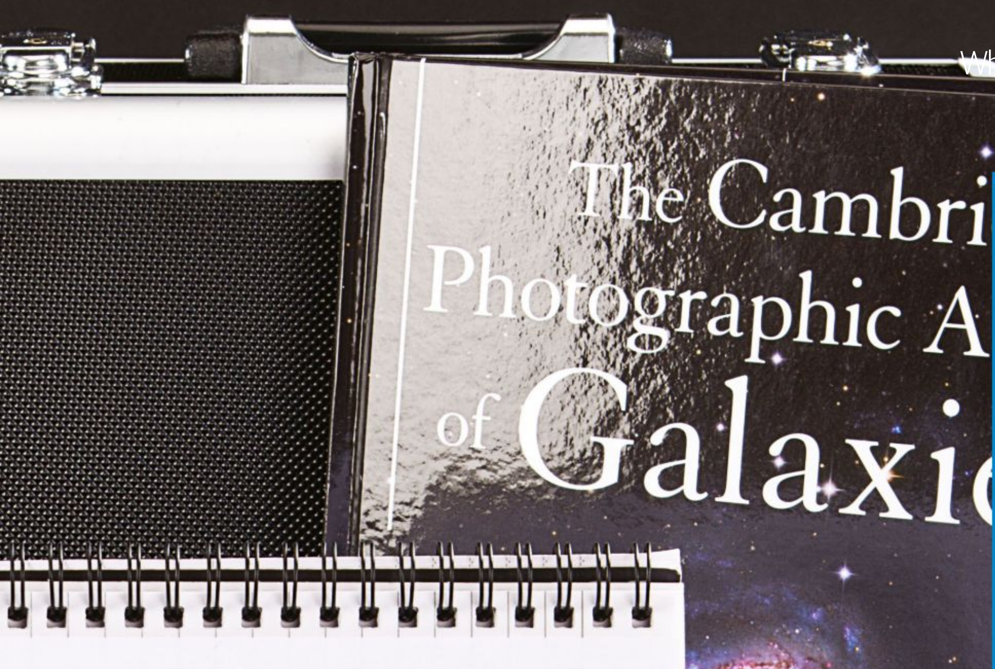
8 MAY
The Eta Lyrids reach their peak of three meteors per hour

12 MAY
Globular cluster Messier 5 is well placed for observation in Serpens at +5.7

12 MAY
Mercury reaches half phase in the evening sky, dazzling at magnitude -0.2

16 MAY
The Moon and Mars pass within 1°28' of each other in Gemini

Source: Wiki Commons © Adam Block/Mount Lemmon SkyCenter/University of Arizona



23 APR

The Pinwheel Galaxy (Messier 101) is well placed in Ursa Major, glowing at +7.9

3 MAY

Conjunction between the Moon and Saturn in Capricornus

3 MAY

The Moon and Saturn pass within 4°02' of each other in Capricornus

© NASA/ESA

6 MAY

The Eta Aquariids reach their peak of 40 meteors per hour

13 MAY

Mercury reaches its highest point in the evening sky, shining at magnitude +0.3

16 MAY

Conjunction between the Moon and Mars in Gemini

17 MAY

Mercury reaches its greatest separation from the Sun in the evening sky at +0.3

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

JARGON BUSTER

Conjunction

This is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Greatest elongation

This is when the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as bright evening stars during greatest eastern elongations and as morning stars during western elongations.

Declination (Dec)

Declination tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it is from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, an object with a magnitude of -1 is brighter than an object with a magnitude of +2.

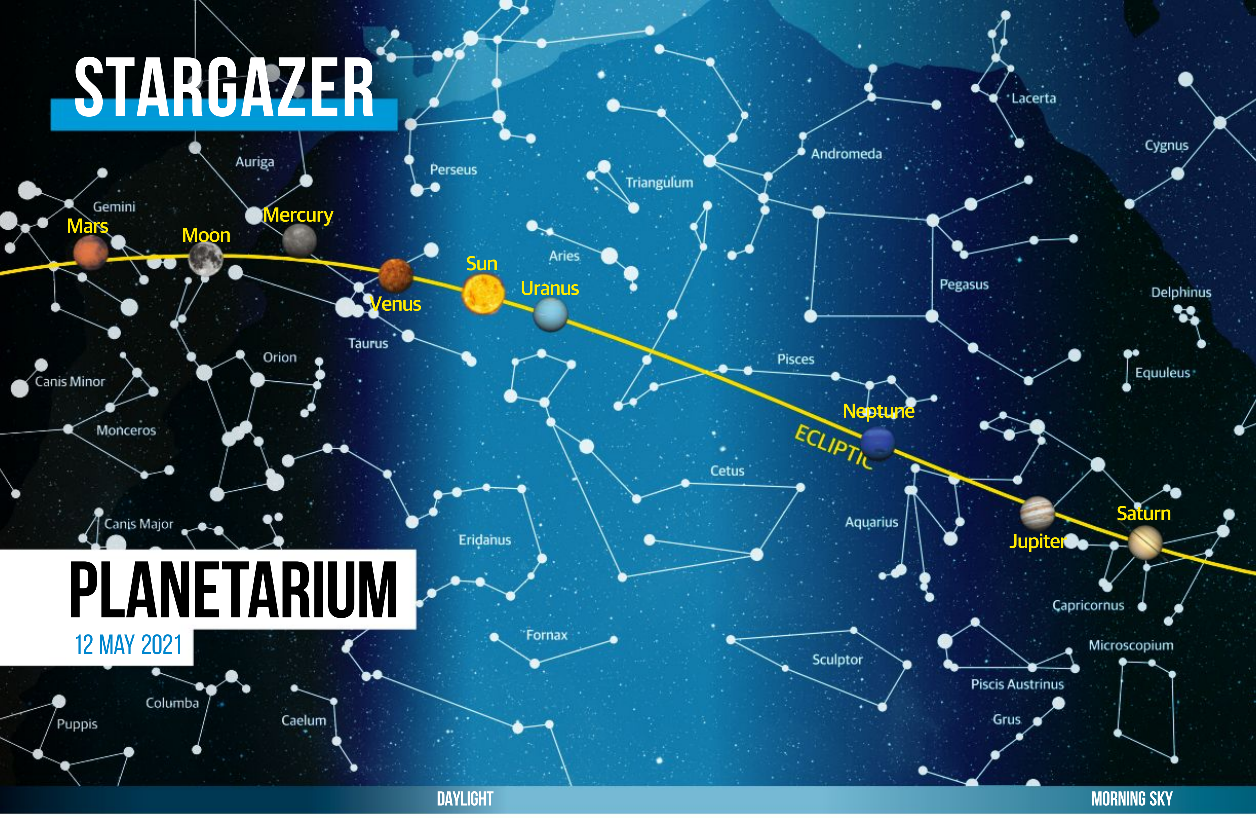
Opposition

This is when a celestial body is in line with the Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter in the sky.

STARGAZER

PLANETARIUM

12 MAY 2021



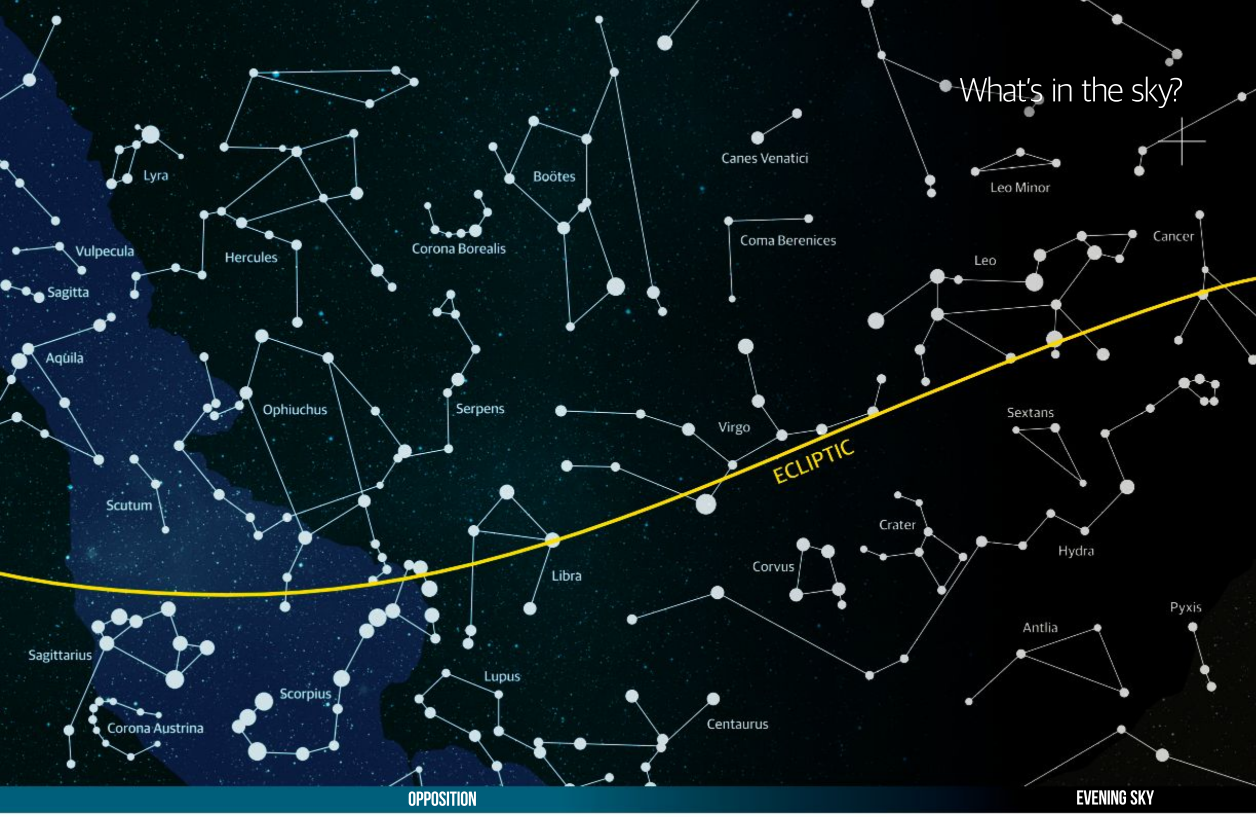
MOON CALENDAR

			22 APR 75.9% ◒04:28 ◓13:47	23 APR 85.1% ◒04:50 ◓15:09	24 APR 92.6% ◒05:09 ◓16:33	25 APR --:--%* ◒05:27 ◓17:59
26 APR 97.7% ◒05:45 ◓19:28	27 APR FM 99.9% ◒06:04 ◓20:59	28 APR 98.8% ◒06:28 ◓22:31	29 APR 94.4% ◒06:59 ◓23:57	30 APR 87.3% ◒07:39 ◓--:--	1 MAY 78.0% ◓01:13 ◒08:33	2 MAY 67.5% ◓02:13 ◒09:40
3 MAY TQ 56.4% ◓02:56 ◒10:54	4 MAY 45.3% ◓03:27 ◒12:11	5 MAY 34.9% ◓03:51 ◒13:27	6 MAY 25.3% ◓04:09 ◒14:40	7 MAY 17.1% ◓04:24 ◒15:50	8 MAY 10.2% ◓04:38 ◒16:59	9 MAY 5.1% ◓04:52 ◒18:08
10 MAY 1.7% ◓05:06 ◒19:17	11 MAY NM 0.1% ◓05:21 ◒20:26	12 MAY 0.5% ◓05:40 ◒21:35	13 MAY 2.8% ◓06:03 ◒22:42	14 MAY 6.9% ◓06:33 ◒23:46	15 MAY 12.8% ◓07:12 ◒--:--	16 MAY 20.2% ◒00:41 ◓08:02
17 MAY 29.1% ◒01:27 ◓09:03	18 MAY 39.0% ◒02:04 ◓10:12	19 MAY FQ 49.7% ◒02:32 ◓11:27	20 MAY 60.8% ◒02:55 ◓12:45			

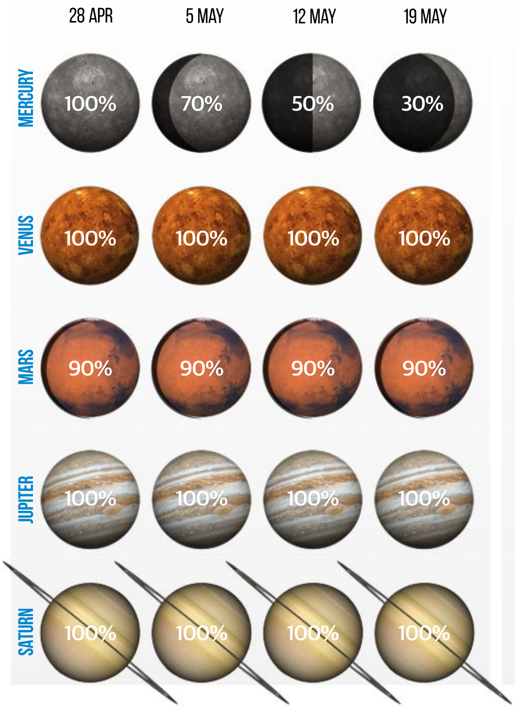
% Illumination
◓ Moonrise time
◒ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

* The Moon does not pass the meridian on 25 April



ILLUMINATION PERCENTAGE



PLANET POSITIONS

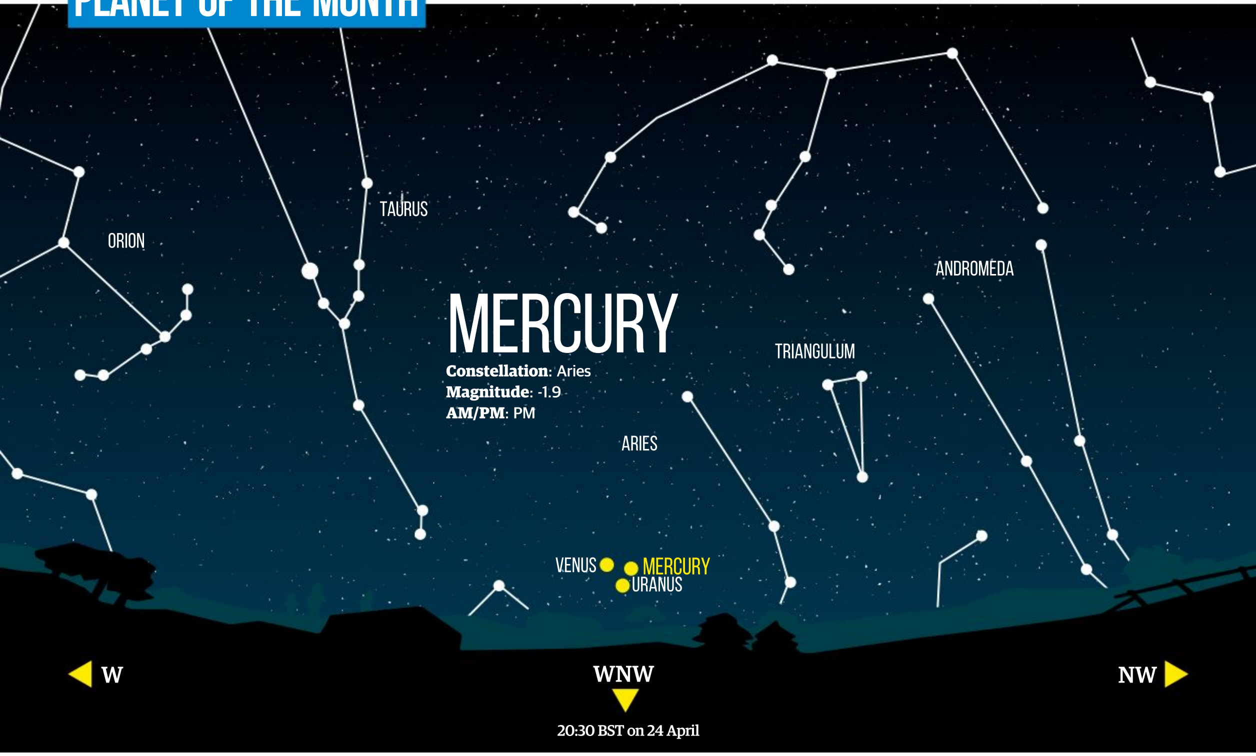
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
22 APR	02h 11m 37s	+13° 10' 42"	Aries	-2.0	06:01	20:33
28 APR	03h 00m 17s	+18° 06' 07"	Aries	-1.4	05:56	21:28
5 MAY	03h 54m 52s	+22° 23' 14"	Taurus	-0.8	05:53	22:25
12 MAY	04h 41m 07s	+24° 40' 57"	Taurus	-0.2	05:53	23:01
19 MAY	05h 14m 43s	+25° 12' 34"	Taurus	+0.6	05:55	23:12
22 APR	02h 26m 01s	+13° 44' 31"	Aries	-3.9	06:12	20:51
28 APR	02h 54m 57s	+16° 12' 05"	Aries	-3.9	06:02	21:11
5 MAY	03h 29m 31s	+18° 45' 24"	Taurus	-3.9	05:53	21:34
12 MAY	04h 05m 00s	+20° 54' 32"	Taurus	-3.9	05:46	21:57
19 MAY	04h 41m 20s	+22° 35' 37"	Taurus	-3.9	05:42	22:18
22 APR	05h 54m 44s	+24° 53' 39"	Taurus	+1.5	08:24	01:39
28 APR	06h 10m 47s	+24° 51' 58"	Gemini	+1.5	08:16	01:31
5 MAY	06h 29m 31s	+24° 42' 10"	Gemini	+1.6	08:09	01:21
12 MAY	06h 48m 14s	+24° 23' 58"	Gemini	+1.6	08:02	01:10
19 MAY	07h 06m 53s	+23° 57' 27"	Gemini	+1.7	07:57	00:57
22 APR	21h 56m 42s	-13° 17' 07"	Capricornus	-2.2	04:11	13:54
28 APR	22h 00m 18s	-12° 59' 12"	Aquarius	-2.2	03:49	13:36
5 MAY	22h 04m 08s	-12° 40' 09"	Aquarius	-2.3	03:24	13:14
12 MAY	22h 07m 31s	-12° 23' 22"	Aquarius	-2.3	02:58	12:52
19 MAY	22h 10m 26s	-12° 09' 05"	Aquarius	-2.4	02:32	12:28
22 APR	21h 00m 14s	-17° 36' 31"	Capricornus	+0.7	03:41	12:32
28 APR	21h 01m 20s	-17° 32' 42"	Capricornus	+0.7	03:18	12:10
5 MAY	21h 02m 21s	-17° 29' 25"	Capricornus	+0.7	02:51	11:44
12 MAY	21h 03m 03s	-17° 27' 28"	Capricornus	+0.7	02:24	11:17
19 MAY	21h 03m 26s	-17° 26' 53"	Capricornus	+0.6	01:57	10:50

THIS MONTH'S PLANETS

Heading into summer affords observers the opportunity to catch the fleeting planet Mercury

PLANET OF THE MONTH



20:30 BST on 24 April

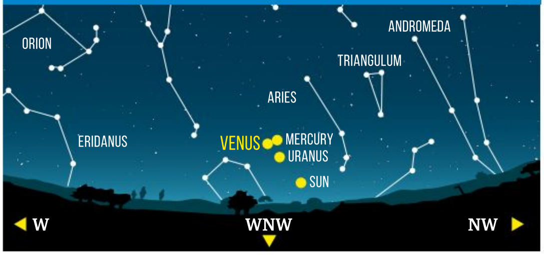
Mercury is one of the Solar System's forgotten planets. It has only been visited by a few space probes, far fewer than almost all the other worlds whirling around our Sun, and although it has a few dramatic features on its surface, it has no vast canyons like Mars or towering mountains like Venus. However, Mercury has its own attractions and claims to fame. Its best known – a huge multi-ringed impact feature called the Caloris basin – is one of the largest such features in the Solar System, and it has fascinating scarps and ridges on its heat-blasted surface.

A surprising number of stargazers and amateur astronomers have never seen Mercury. Many have not even tried to look for it, believing that it is too difficult to see because of its close proximity to the Sun. And while it's true that most of the time Mercury is lost in the Sun's glare, when it is best placed in the sky it is quite obvious to the naked eye – and it will be well placed this month.

At the start of our observing period Mercury will be very low in the west-northwest right after sunset, too low to be seen and setting just 20 minutes after the Sun. As the days pass it will climb higher, becoming more easily visible. It will pass brighter and more obvious Venus on the evenings of 24 and 25 April – this will be a good time to look for it in binoculars, once the Sun has set, of course. By 1 May Mercury will have moved so far from the Sun that it won't set until an hour after it. On the evening of 4 May it will move past the Pleiades star cluster – another great opportunity to see it in binoculars – and after sunset on 13 May it will be shining in the twilight close to a beautiful crescent Moon.

At the end of our observing period Mercury will be setting almost two hours after the Sun, and will be an easy naked-eye object, looking like a copper-hued star in the deepening twilight. If Mercury doesn't jump out at you right away, don't worry: many observers find it useful to scan the sky with their binoculars first, pinning-down its position in relation to trees or other objects on the horizon to make it easier to find when the sky is a little darker.

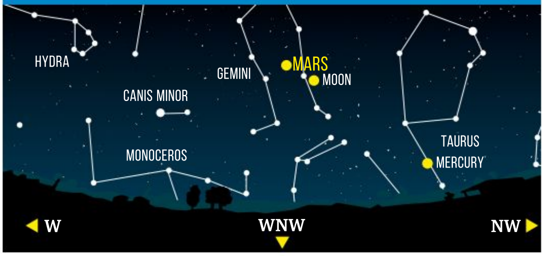
VENUS 20:00 BST on 25 April



Constellation: Aries **Magnitude:** -3.9 **AM/PM:** PM

That magnitude sounds amazing, but Venus will be so low after sunset that it will be difficult to see in the twilight. At the start of our observing period Venus will be setting only half an hour after the Sun. It will move away from it as the days pass, but won't be much more obvious. It should be visible to the naked eye, but hills, trees or buildings on your horizon will hide it.

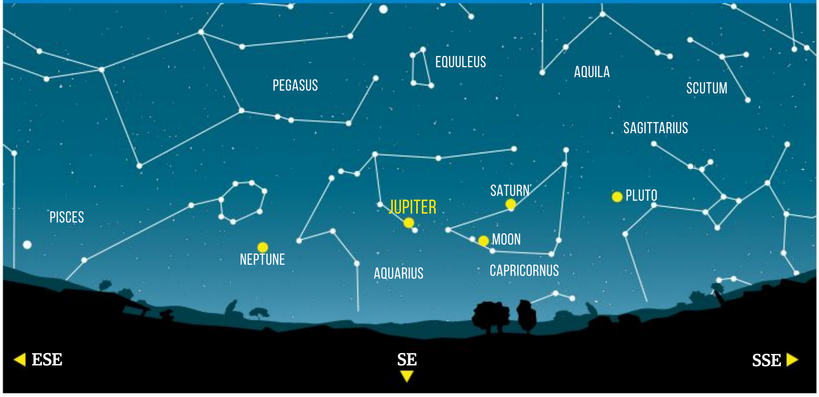
MARS 22:00 BST on 15 May



Constellation: Taurus **Magnitude:** +1.5 **AM/PM:** PM

As April drifts into May, Mars will be visible as an orange 'star' low in the west soon after sunset, close to the border between Taurus and Gemini. Although it won't be strikingly bright – it will shine roughly as brightly as the stars of Orion's Belt – Mars' distinctive marmalade hue will draw the eye away from the many paler stars around it.

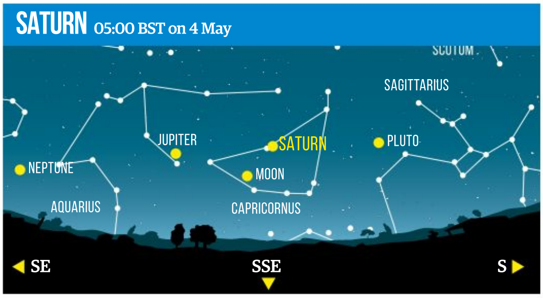
JUPITER 05:00 BST on 4 May



Constellation: Capricornus
Magnitude: -2.2
AM/PM: AM

This won't be the best month to see Jupiter. At the start of our observing period it can be found very low in the southeast before sunrise, but it will rise so shortly before the Sun that it will be difficult to pick out from the bright sky, and any trees or buildings on your skyline in that direction will hide it from view. By the end of our observing period it will have moved far enough away from the Sun that it will be rising an hour and a half before sunrise, making it easier to see. By then you should also be able to see fainter and paler Saturn shining nearby to its right.

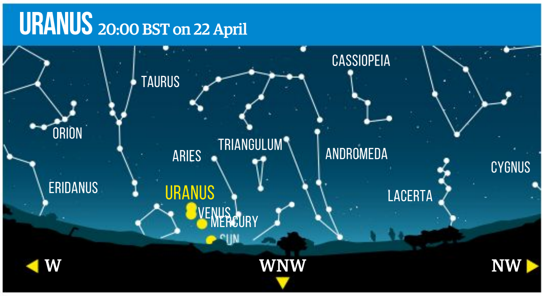
SATURN 05:00 BST on 4 May



Constellation: Capricornus **Magnitude:** +0.7 **AM/PM:** AM

Saturn will be keeping brighter Jupiter company in the morning sky, but the Ringed Planet will also be so low in the sky before sunrise that it will be a challenge to see it, at least before the end of our observing period. You really will need to be looking out at a low, flat southeastern horizon on a perfectly clear, perfectly still morning if you're going to see it.

URANUS 20:00 BST on 22 April



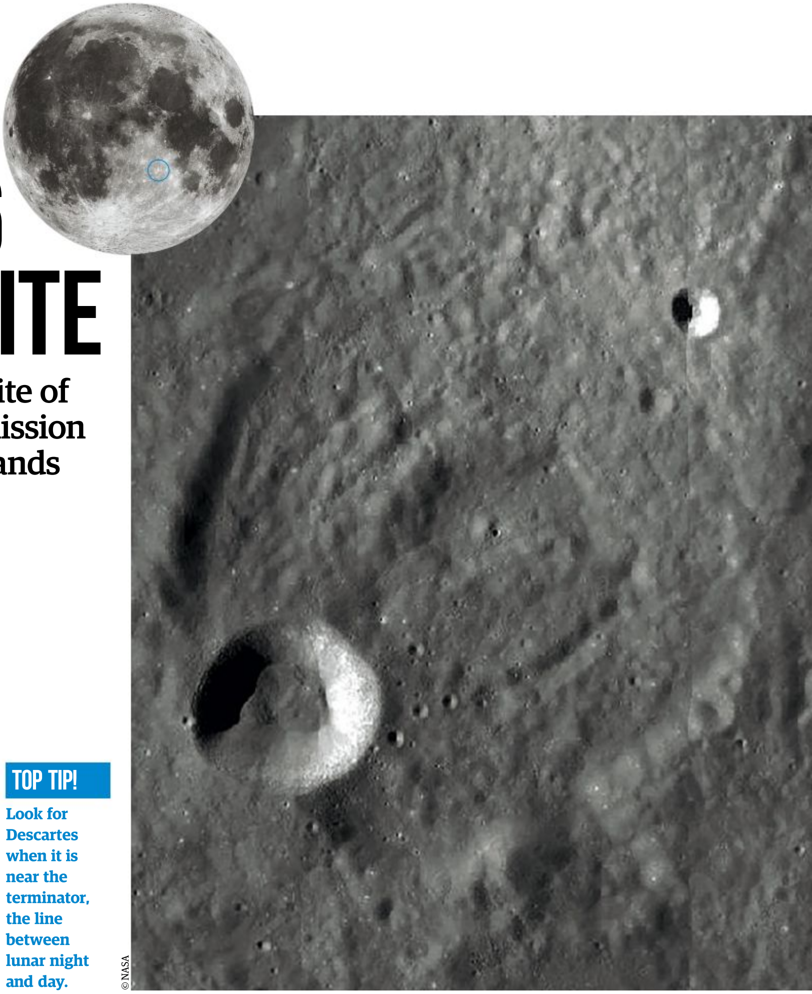
Constellation: Aries **Magnitude:** +5.9 **AM/PM:** PM

At the start of our observing period Uranus will be tucked up tight against bright Venus, less than half a degree – or one Moon diameter – away from it on 22 April, but the pair will be very low in the twilight sky after sunset. You might see them through binoculars or a telescope, but certainly not with your naked eye.

MOON TOUR

APOLLO 16 LANDING SITE

Track down the landing site of the penultimate Apollo mission in the rugged lunar highlands



© NASA

Two years ago we celebrated the 50th anniversary of the Apollo 11 mission, which saw the first humans walk on the surface of the Moon. One thing that became clear during those anniversary celebrations was that many people seem to believe that Apollo ended with the Eagle's landing, and that everything which followed was just a postscript. That's just not true. Every subsequent mission had its own highlights and its own firsts, even if they have now been largely forgotten by everyone except space historians and Apollo fanatics. And if any mission deserves the title of 'the forgotten Apollo mission', it would be Apollo 16, which went to the Moon 49 years ago.

Apollo 16 landed 50 kilometres (31 miles) to the north of the crater Descartes, and unlike the missions that had preceded it, which all had landing sites in relatively smooth areas, it came down in a very rugged area known as the Descartes Highlands. That was deliberate: the purpose of the second J-series mission was to study and collect samples of rocks from an area unlike any visited before in order to advance lunar science. In their 71 hours on the lunar surface, the crew of the lunar module 'Orion' – including the legendary John Young, who went on to fly the Space Shuttle – drove more than 26 kilometres (16 miles) in their rover and collected more than 95 kilograms of samples, including 'Big Muley', the largest rock collected during the whole Apollo program.

Apollo 16 was an amazing mission for so many reasons, but seems to have been lost in the glare of the flights that came before and went after it. Almost half a century after Apollo 16 explored the Moon, why not take a few moments on the next clear night to track down its landing site with your telescope?

First you'll need to find the crater Descartes, and that's not easy because Descartes is more like what's left of a crater than an actual crater. 48 kilometres (30 miles) wide and one kilometre (0.6 miles) deep, Descartes is very old, formed so long ago that only its southwestern rim now stands out prominently from the surface. Its northern rim has almost completely vanished, and the rest has been worn away by time or blasted apart by more recent impacts. One of those impacts blasted a smaller crater, Descartes A, out of its southern edge. Inside Descartes itself are several ridges, all of which have been worn down like the walls of the crater itself. A bright patch of material on its northern edge catches the eye.

Although Descartes is not a prominent lunar landmark, luckily for us it is near some. The key to finding it is to start with a very prominent and well-known chain of three large craters found towards the centre of the Moon: Ptolemaeus, Alphonsus and Arzachel. To the right of Ptolemaeus is another large crater, Albategnius, and if you look to its right, the next large crater in that direction is Abulfeda. Descartes is just a short distance above that. You'll only be able to spot it when it's close enough to the terminator for what's left of its rim and internal features to cast shadows, but it's worth the trouble. When you have Descartes in the middle of your eyepiece, you'll have the Apollo 16 landing site in the same field of view, above or below the crater depending on the type of telescope you're using.

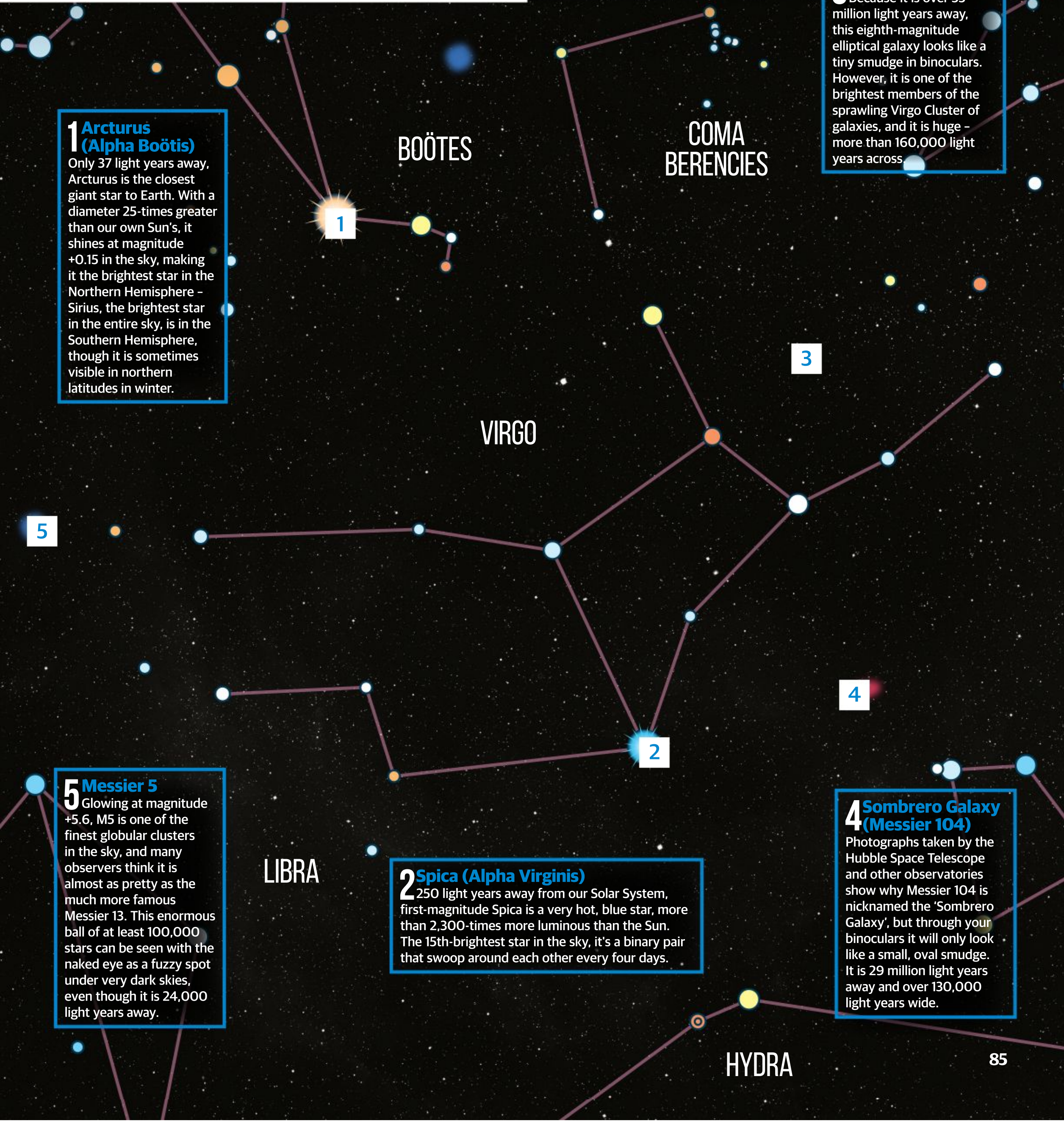
At the start of our observing period Descartes will be well placed for observation, in sunlight in the centre of the Moon, to the right of the terminator and just to the left of the major crater Albategnius. Although Descartes itself won't jump out in an eyepiece, both the previously mentioned bright patch on its northern edge and the smaller crater Descartes A on its southern rim will draw your attention to it. The crater will remain in full view until 2 May, when the terminator will approach and then sweep over it, plunging it into darkness once more.

TOP TIP!

Look for Descartes when it is near the terminator, the line between lunar night and day.

NAKED EYE & BINOCULAR TARGETS

Find the brightest stars of Boötes and Virgo and explore the sky around them



1 Arcturus (Alpha Boötis)

Only 37 light years away, Arcturus is the closest giant star to Earth. With a diameter 25-times greater than our own Sun's, it shines at magnitude +0.15 in the sky, making it the brightest star in the Northern Hemisphere – Sirius, the brightest star in the entire sky, is in the Southern Hemisphere, though it is sometimes visible in northern latitudes in winter.

2 Spica (Alpha Virginis)

250 light years away from our Solar System, first-magnitude Spica is a very hot, blue star, more than 2,300-times more luminous than the Sun. The 15th-brightest star in the sky, it's a binary pair that swoop around each other every four days.

3 Messier 49

Because it is over 55 million light years away, this eighth-magnitude elliptical galaxy looks like a tiny smudge in binoculars. However, it is one of the brightest members of the sprawling Virgo Cluster of galaxies, and it is huge – more than 160,000 light years across.

4 Sombrero Galaxy (Messier 104)

Photographs taken by the Hubble Space Telescope and other observatories show why Messier 104 is nicknamed the 'Sombrero Galaxy', but through your binoculars it will only look like a small, oval smudge. It is 29 million light years away and over 130,000 light years wide.

5 Messier 5

Glowing at magnitude +5.6, M5 is one of the finest globular clusters in the sky, and many observers think it is almost as pretty as the much more famous Messier 13. This enormous ball of at least 100,000 stars can be seen with the naked eye as a fuzzy spot under very dark skies, even though it is 24,000 light years away.

Pacman Nebula
(NGC 281)

DEEP SKY CHALLENGE

THE VAIN QUEEN'S DEEP-SKY DELIGHTS

How to track down some of Cassiopeia's most sneakily concealed crown jewels

Naked-eye observers might love Cassiopeia because it is so easy to spot in the sky, but most telescope users don't pay the distinctive W-shaped constellation much attention. They tend to skip over or past it as they swing their instruments towards its neighbours, eager to see the 'celebrity' deep-sky objects around it.

Nearby Perseus has the stunning and famous Double Cluster, Taurus has the Pleiades (Messier 45) and Andromeda has the amazing Andromeda Galaxy (Messier 31). But it's definitely worth taking the time to look a little more closely at Cassiopeia, the infamously vain queen of the sky, because if you do you'll find a surprising number of attractive deep-sky objects hidden within the folds of her royal robes.

The star cluster Messier 103 might have been the very last object Messier put in his catalogue, but it's far from the least attractive; it is one of the hidden gems of the night sky, but needs to be seen through as big a telescope as possible. If you're lucky enough to find yourself at your telescope's eyepiece on a beautiful dark night with no Moon or light pollution, the nearby Owl Cluster (NGC 457) is also worth a look.

Close to the naked-eye star Gamma Cassiopeiae, you'll find not one but two swirly nebulae known as IC 59 and 63 - collectively the Gamma Cassiopeiae Nebula - but you'll need your best eyepiece and perfect seeing to glimpse the dark lanes and knots of dust within these beautiful subtle arcs of misty light.

NGC 663

Source: Wikipedia Commons © Hewholooks

> “YOU’LL NEED YOUR BEST EYEPIECE AND PERFECT SEEING TO GLIMPSE THE DARK LANES AND KNOTS OF DUST WITHIN THESE BEAUTIFUL SUBTLE ARCS OF MISTY LIGHT”

1 Messier 103

The final object catalogued by the comet hunter Charles Messier, the 40-plus stars of this +7.4 arrowhead-shaped cluster are a beautiful sight in a large telescope’s low-power eyepiece.

3 Pacman Nebula (NGC 281)

This bright nebula is nicknamed the Pacman Nebula after its resemblance to the arcade game character, but its fascinating interior details are only visible in larger telescopes.

5 NGC 559

A challenge for large telescopes on dark, Moon-free nights, this magnitude +9.5 cluster is little more than a spray of faint stars barely 4.4′ across. It is also known as Caldwell 8.

2 Gamma Cassiopeiae Nebula (IC 59 and 63)

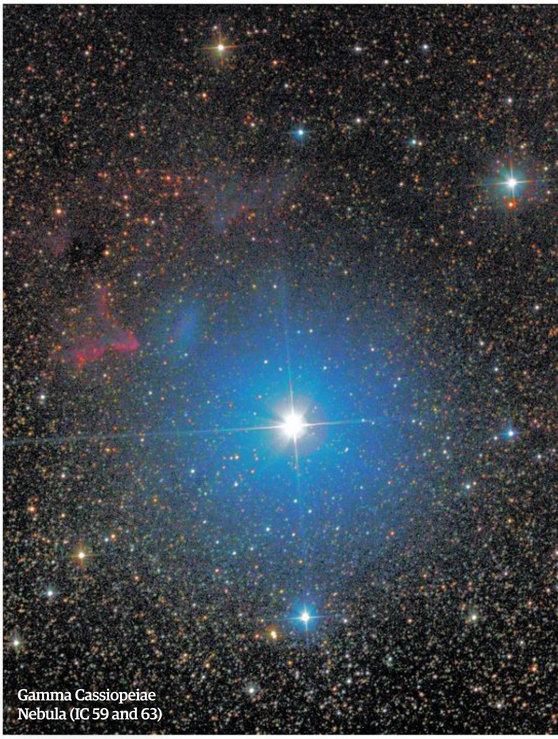
This close pair of crescent-shaped nebulae look very pretty in a large telescope’s high-power eyepiece, but any details or structure are drowned out by light pollution.

4 NGC 663

This seventh-magnitude open cluster is 8,000 light years distant, but covers just 15′ of sky. Containing around 60 stars – most much fainter than seventh magnitude – it is best seen through a high-power eyepiece.

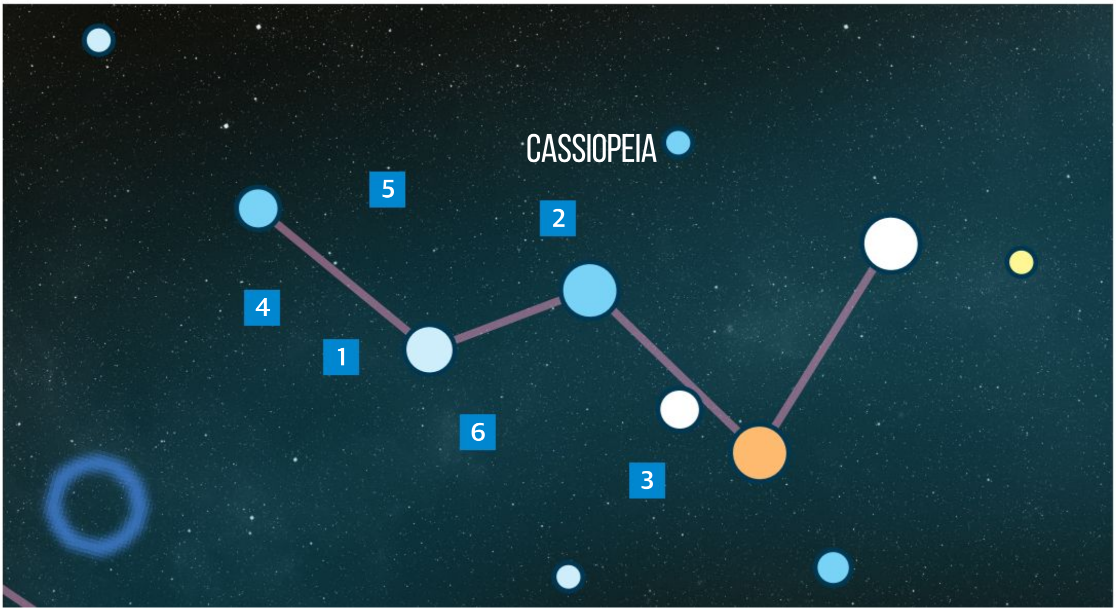
6 Owl Cluster (NGC 457)

This cluster is one of the finest in the region. Large telescopes will resolve the triangle-shaped cluster’s compressed centre and three lines of fainter stars leading away from it.



Gamma Cassiopeiae Nebula (IC 59 and 63)

Source: Wikipedia Commons © Neil Michael Wyatt



THE NORTHERN HEMISPHERE

Spring lets us gaze out of our galaxy's plane, revealing new targets

Bright yellow-white star Capella of Auriga (the Charioteer) sits low in the northwestern sky this month, a striking sight at magnitude +0.08 alongside easy-to-locate Castor and Pollux of Gemini (the Twins). Ursa Major's 'Big Dipper' is the simplest asterism to find as soon as darkness falls, making it easy to use its pointer stars to find Polaris. Follow the pointers in the other direction and you will find bright-white star Regulus in Leo (the Lion); trace your finger along the bowl and you'll find yourself led to brilliant yellow-orange star Arcturus in the constellation of Boötes (the Herdsman). Nearby, just northeast of Arcturus, you'll be greeted by the unmistakable semi-circle of the Northern Crown, Corona Borealis.

USING THE SKY CHART

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

MAGNITUDES

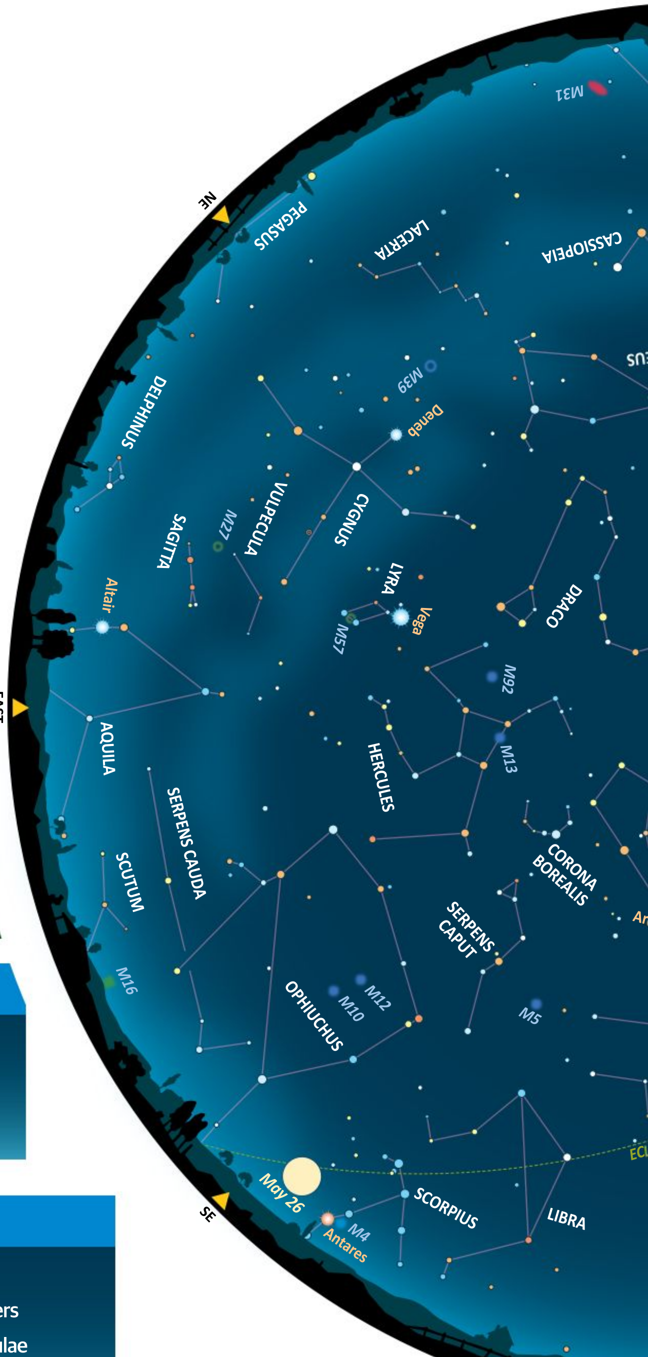
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- • 1.0 to 1.5
- • 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- · 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ◉ Variable star

SPECTRAL TYPES

● ●	O-B	● ●	G
● ●	A	● ●	K
● ●	F	● ●	M

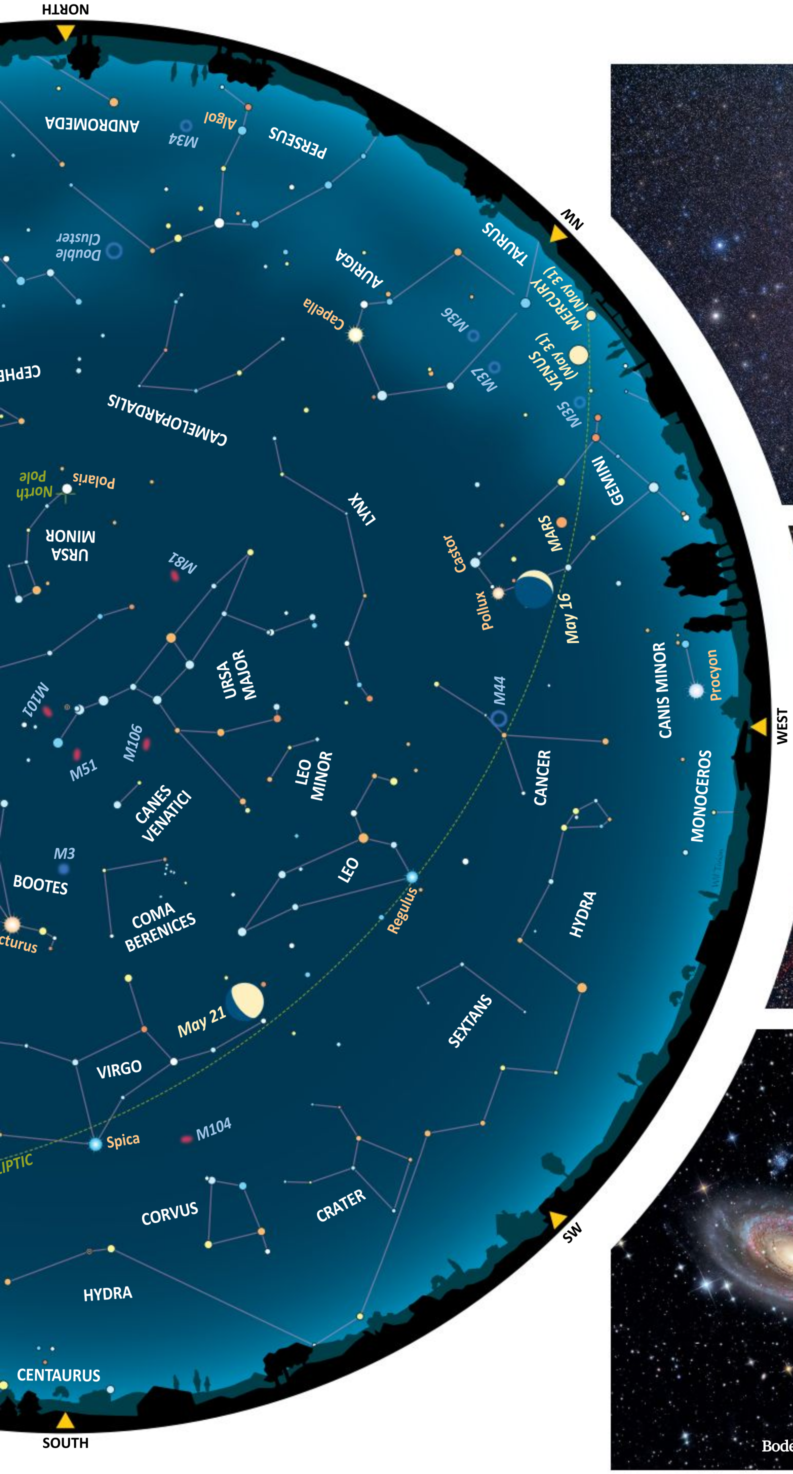
DEEP-SKY OBJECTS

- ○ ○ Open star clusters
- ● ● Globular star clusters
- 🟩 🟩 Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ● ● Galaxies



Observer's note

The night sky as it appears on 17 May 2021 at approximately 22:00 (BST)



Gemini constellation

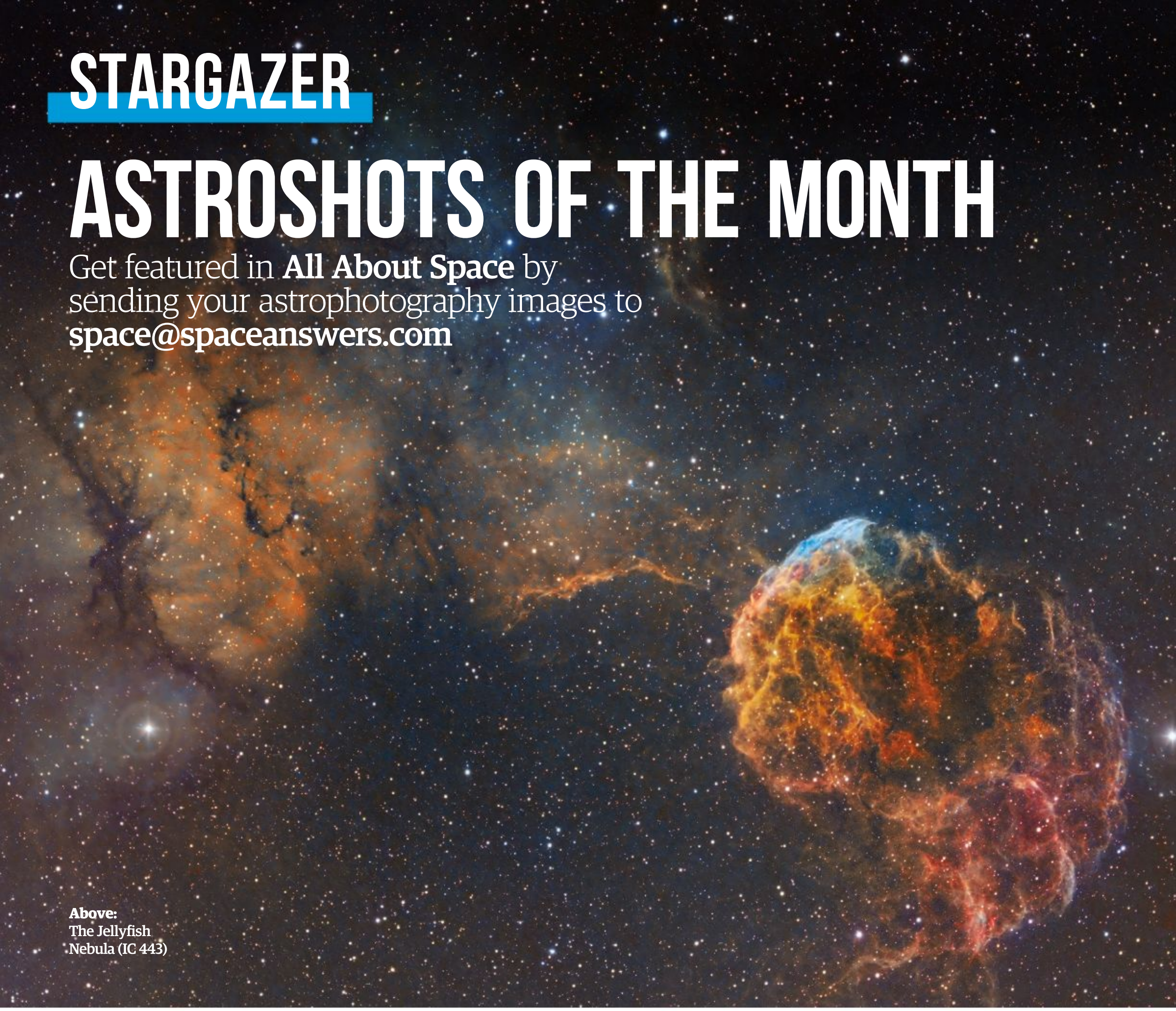
© Getty

Flaming Star Nebula (IC 405)

© Getty

Bode's Galaxy (Messier 81) and the Cigar Galaxy (Messier 82)

© Getty



ASTROSHOTS OF THE MONTH

Get featured in **All About Space** by sending your astrophotography images to **space@spaceanswers.com**

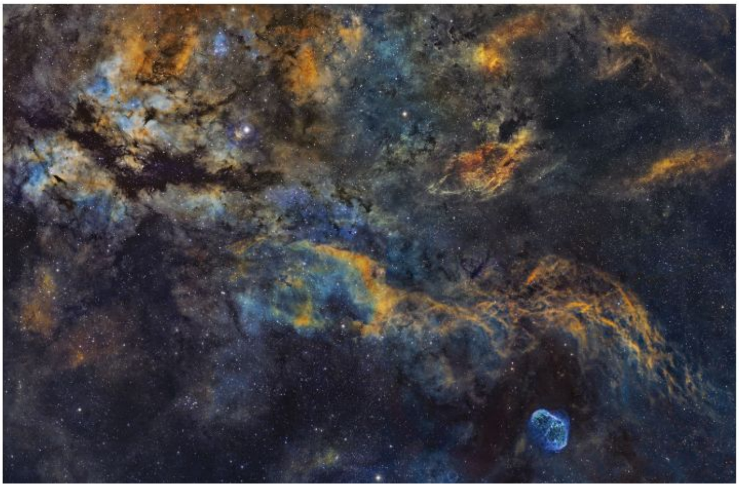
Above: The Jellyfish Nebula (IC 443)

Paul Swift

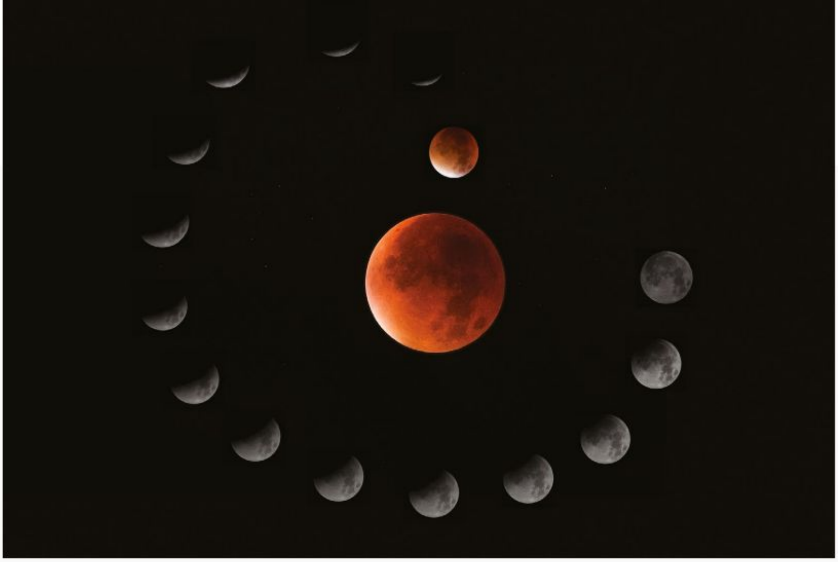
Location: Valencia, Spain

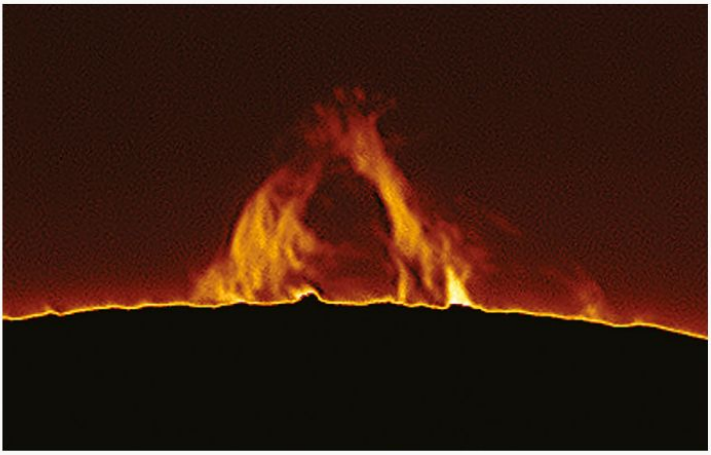
Telescope: Vixen VSD 100 f/3.8

"I have a background in the arts and worked professionally as a cinematographer and lighting cameraman, so astrophotography made for a natural change in focus. I have always wanted to turn my camera to the night sky, and moving from London to the less light-polluted city of Valencia, Spain, presented me with the perfect opportunity to do just that. The combination of exploring deep space and the creative and technical art form that is astrophotography has offered a powerful and alluring vocation. On any clear night I can be found setting up under darkening skies for a night of astrophotography.



Right: Nebulosity around Gamma Cygni





Above: Lunar phases leading up to a ruddy blood Moon

Left: The Sun's tempestuous surface

Roger Hutchinson

Location: Wimbledon, London

Telescope: Lunt LS60 solar telescope, Celestron EdgeHD 11"

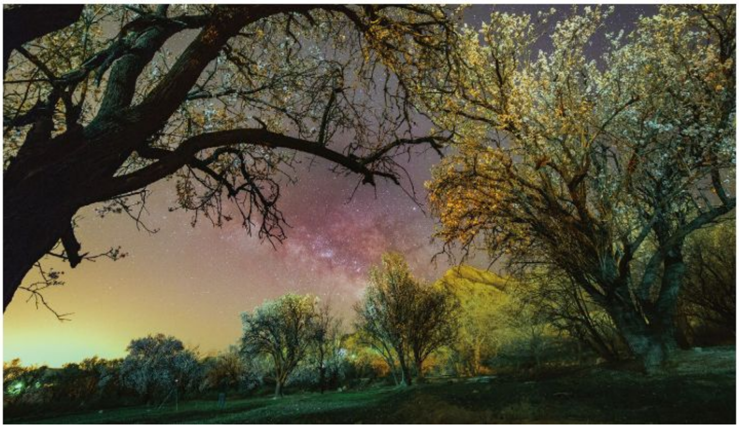
"I first became interested in astronomy and space as a child growing up in the 1970s, right at the end of the Apollo program. My dad helped me build an 8" Dobsonian telescope, through which I caught my first sight of Saturn and the craters and mountains of the Moon. I think I was hooked from that point. I started imaging with an old film SLR camera, but the results were never what I had hoped for, so I parked my ambition until digital photography came along. For the past five or six years I have been pursuing my hobby in astrophotography over observational astronomy. Some things never change, and my favourite targets are still the planets and the lunar surface."

> "MY FAVOURITE TARGETS ARE STILL THE PLANETS AND THE LUNAR SURFACE"

Amir Shahcheraghian

Location: Mogham Port, Iran

"My passion for astronomy has existed since childhood and ignited my interest in nightscape astrophotography. I enjoy nothing more than setting up a DSLR camera on a tripod and taking images of the night sky. In order to capture as many targets as I can, I travel around Iran and shoot from a variety of locations, from deserts to mountains. Just recently I shot the Milky Way rising over some blossom trees."



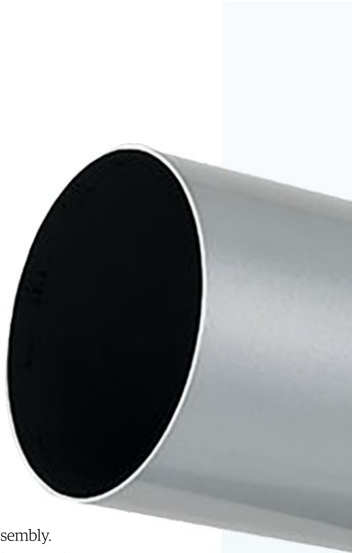
Right: The Milky Way's centre

REVIEW

CELESTRON STARSENSE EXPLORER DX 102AZ

This telescope's innovative technology provides the simplest and quickest solution yet to finding objects to observe

Reviewed by Robin Scagell



TELESCOPE ADVICE

Cost: £349.99 ($480)
From: Celestron
Type: Refractor
Aperture: 4"
Focal length: 25"

BEST FOR...

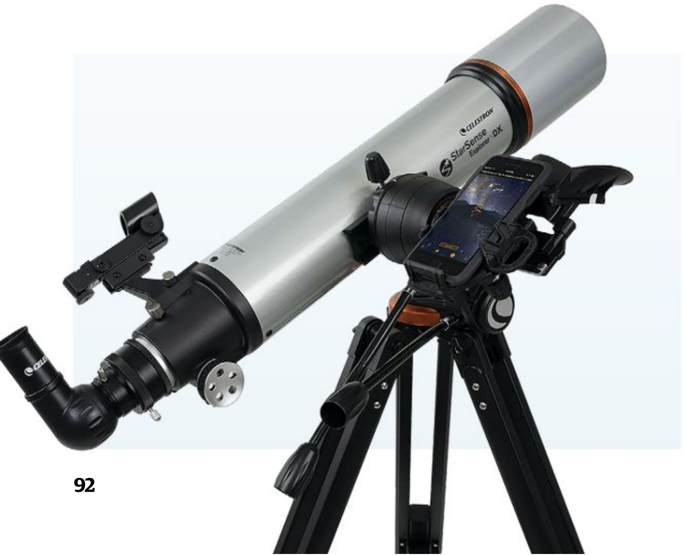
- BEGINNERS
- MEDIUM BUDGETS
- PLANETARY VIEWING
- LUNAR VIEWING
- BRIGHT DEEP-SKY OBJECTS

There are four instruments in the Celestron StarSense Explorer range: an 80mm refractor, a 114mm reflector, the 102mm refractor under test and a 130mm reflector. All these instruments are standard members of the Celestron range and are available in other mounting packages. In this range, the 80mm and 114mm are supplied on lighter weight mountings, while the 102mm and 130mm have the same heavier mounting. The alt-azimuth mounting means you can move the instrument around two axes – up and down and from side to side. This is the simplest form of mounting, and is particularly suitable for a beginner. The alternative equatorial mounting, with one of its axes tilted at the same angle as your latitude, not only confuses many beginners, but has the drawback that it involves an overhanging load usually balanced with a counterweight, reducing the portability.

The mounting of the DX 102 is completely manual, with flexible rods to allow what are called slow motions, providing a finer control over the movement than simply pulling and pushing the instrument. The extra ingredient over a standard manual mounting is the attachment for a smartphone, directly fixed to the central assembly. This is not to be confused with smartphone attachments that simply enable you to take photos of bright objects through the eyepiece, as found on some other beginners' instruments.

This is an achromatic refractor with a 102mm doublet lens composed of two different types of glass. It has a focal ratio of f/6.5, which means that it has a comparatively short tube for its diameter – a situation that provides a wide field of view and bright image with a fairly compact instrument. Achromatic implies a freedom from the false colour that bedevilled refractors in the very early days of telescopes, but this is a comparative term. Like other achromatic refractors, the instrument still has some false colour, which shows as coloured fringes around the edges of objects, particularly at high magnification, and the short tube results in inherently more false colour than an achromatic instrument with a longer focal ratio. To completely overcome false colour you need a considerably more expensive apochromatic refractor or a reflector. However, refractors are traditionally more robust than reflectors, so there is no ideal instrument to suit everyone.

The package comes with two eyepieces, giving two useful magnifications of 26 and 66, and what is termed an erect-image diagonal. A star diagonal is standard with astronomical refractors, and reflects the beam from the focuser through 90 degrees to allow a much easier observing position than crouching on the ground looking up through the tube, but usually it has the drawback of reversing the image as in an ordinary mirror. The diagonal provided by Celestron use a roof prism rather than a simple mirror, giving a non-reversed image so you can use the instrument by day as well as by night. It also avoids the confusion of viewing the moon's features or star fields back to front. Finally,



Main: The short tube of this refractor gives a focal ratio of f/6.5

Right: The telescope sits upon a sturdy alt-azimuth mount

“PROVIDES A WIDE FIELD OF VIEW AND BRIGHT IMAGE WITH A FAIRLY COMPACT INSTRUMENT”

there is a standard red-dot finder to help in pointing the telescope at objects. This is necessary when aligning the telescope, as you need to point it at a recognisable object at the start of observing.

The instrument comes in just two main parts – the tripod and the tube assembly – so it seems straightforward. The accessory tray that sits in the middle of the tripod legs, however, needs to be attached by fiddly little thumb screws that are already in place, but the wrong way round in their holes! This is poor design, as these screws will quickly get lost. A simple slot-and-turn system would be much less aggravating, unless you intend to use the instrument solely as a piece of furniture permanently set up in the corner of the room – or do without the tray altogether.

The telescope attaches to the mount using a standard dovetail, but as it came out of the box the clamp assembly was twisted through 180 degrees, with the locking screw at the bottom. The instructions tell you to turn it, but this is easier said than done. Many beginners will wonder if they are meant to be forcing this round at all. In fact, you do need to apply a lot of force to twist it. Confusingly, the instructions then refer to the knob at the bottom of the clamp.

Once set up, you need to align the red-dot finder with the main instrument by day. Unfortunately the adjustment range on the device supplied did not allow it to be aligned accurately, and for the test we used another that we already had.

The final step is to remove the cap from the mirror on the StarSense dock – again courageously pulling it off with some effort – and fitting your smartphone into the spring-loaded slider. Bear in mind that not all smartphones will work, and check your model against a list on the Celestron website before taking the plunge. It must have a camera sensitive enough to image the brighter stars using a night setting.

We're pleased to report that loading and using the software on a Moto G8 was easy and quite intuitive. This was fortunate, as the quick start manual ends at this point. All the following stages are accomplished using the StarSense app that you need to unlock using a code supplied with your instrument, which will work with up to five devices.

The camera views the sky through a mirror, enabling you to view the phone's screen at a convenient angle. The StarSense app displays the camera's view of the night sky using a time exposure if necessary, so it may take some seconds to appear or refresh. The method of alignment is to aim the telescope at a chosen object – which is where the red-dot finder comes in handy – and then move the red crosswires on the app to the same object shown on the phone view. You can zoom in for better precision.

Once complete you are in business, and you can choose from a list of objects observable with this instrument at the time, graded according to whether they can be seen from the city or from a dark sky. Once chosen, you'll see a set of arrows on the screen that tell you which way to move the telescope to get to that object. Within seconds you are on target, and the crosswires turn green. Moving from one object to another takes just seconds – the quickest finding system we've seen.

Some drawbacks did become evident. The finding system is not always spot on, so you need to be prepared to search for objects around the edge of the field of view. The clutch that holds the telescope in altitude, on the test model at least, was fierce, so to move it you need to grasp the tripod firmly with one hand and wrench the tube up or down with the other. The altitude slow motion is equally stiff to turn, while the azimuth control had an annoying backlash.

One major source of problems was the mirror, which is crucial for finding objects. The software constantly checks the alignment of the instrument, complaining if it can't see the sky, so snapping on the cover in between observations is not easy or ideal. The mirror can become dewed up within minutes on some nights – often the clearest. Unlike household mirrors, its reflective coating is on the front surface rather than the back, so regularly wiping it clear could result in damage to the coating. Unwary users are likely to try polishing it with glass cleaner or even abrasive solutions.

Optically the telescope is well up to standard for a short-focus achromatic refractor, and is well suited to deep-sky observing. The eyepieces supplied, although in lightweight plastic barrels, are of good optical quality. Boosting the magnification using a Celestron 2x Barlow lens revealed false colour in lunar and planetary images, so this is not an ideal high-power or planetary instrument. The erect-image diagonal, which allows the instrument to focus, introduces very little distortion, only marginally noticeable on a star image using a magnification of 130x.

Once you're accustomed to the instrument, finding objects is extremely quick and fun. The optical quality is good for a telescope of this type, but for planetary observing a different instrument would be preferable, such as the 130mm reflector from the same range. The clunky movement and delicate mirror could limit the usefulness of the instrument for more detailed observations, but the system certainly does get you observing within just a few minutes, unlike more advanced instruments, thus overcoming one of the greatest hurdles that beginners face.

The pricing of this instrument is not significantly less than that of the Celestron NexStar 102 SLT, the same instrument on a fully motorised mount, which has the great advantage of tracking objects for you. Whether you buy this model or opt for the full Go-To version, or indeed the NexStar 130 SLT reflector, is a decision that you will have to make depending on your observing interests.

FOR

- ⊕ Very easy to use and quick to find objects
- ⊕ Almost intuitive push-to method of homing in
- ⊕ Excellent on-screen information and listing of objects to view in a night's observing
- ⊕ Sensible choice of eyepieces provided and good optical quality for deep-sky observing

AGAINST

- ⊖ Alignment procedure depends on a mirror
- ⊖ Dews up quickly
- ⊖ Slow motions are somewhat clumsy
- ⊖ Instrument stiff to move

> "LOADING AND USING THE SOFTWARE ON A MOTO G8 WAS EASY AND QUITE INTUITIVE"

Below: Two lenses, an erect-image diagonal and red-dot finder are included

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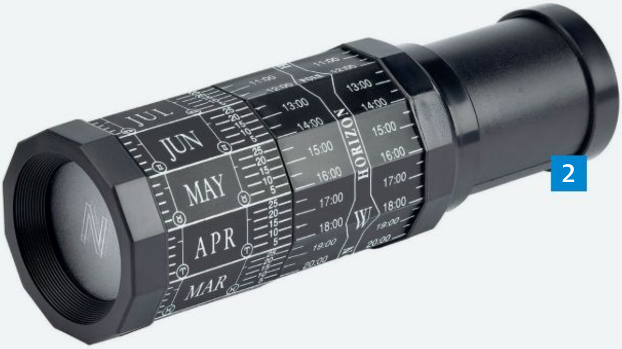

2

FOR KEEPING WARM

ESA PATCH BEANIE

Cost: €22.90 (approx. £19.70 / $27.10)

From: esaspaceshop.com

1 A fitting beanie for space enthusiasts, it features the official European Space Agency patch worn by ESA astronauts. Made from 100 per cent acrylic, with a one-size-fits-all approach this beanie is designed with everyone in mind. The beanie is available in either royal blue or navy blue, and the patch includes the flags of 22 ESA Member States. The ESA patch was redesigned in 2020 to also include two Associate Members, Latvia and Slovenia, and one Cooperating State, Canada. It can keep your head warm while you're out observing!

FOR EASY NIGHT-SKY NAVIGATION

STELLARSCOPE STAR FINDER

Cost: £35 (approx. $48)

From: shop.rnli.org

2 Never lose track of the stars again. Simply set the dials on the barrel to the hour and date required and view the stars and constellations that are available. The practical design allows you to view the computer-generated star map – about four centimetres (1.5 inches) in diameter – with one eye while observing the night sky with the other. The Stellarscope Star Finder is approximately 19 centimetres (7.5 inches) long and comes with latitude compensation rings as well as Northern and Southern Hemisphere star map inserts.

FOR LONG OBSERVING SESSIONS

CELESTRON LITHIUM 7.2 AH LIFEPO4 POWERTANK

Cost: £139 (approx. $191)

From: firstlightoptics.com

3 Scrambling around for batteries in the dark will be a thing of the past. Keep your devices powered with this sturdy outdoor charging solution, designed to be smaller, lighter, safer and easier to maintain compared to lithium-ion and sealed lead-acid designs. With up to 2,000 charge cycles and a shelf life of up to ten years, the performance of this powertank is a cut above the rest. Features a telescope power output, two USB charging ports and has a charge time from flat of just three hours.

5

> “EACH MEMBER OF THE SOLAR SYSTEM HAS BEEN TRANSFORMED INTO A UNIQUE CHARACTER”

4

6

FOR GAMERS

SURVIVING MARS

Cost: from £23.99 / $29.99

For: Playstation 4, Xbox One, PC, Mac, Linux

4 Do you think you have what it takes to build a colony on Mars? This single-player strategy game from Paradox Interactive and Haemimont Games is guaranteed to put your planning skills to the test. Where will you choose to settle? What resources do you have? How will you explore new horizons? This isn't just about building a colony – it's about survival. With ample expansion packs available, *Surviving Mars* continually challenges and entertains as you discover the countless mysterious sci-fi secrets Mars has to offer.

FOR YOUR HOME

NIGHT SKY UNDERGROUND MAP LARGE POSTER

Cost: £10 (approx. $13.75)

From: shop.rmg.co.uk

5 Fancy a commute of cosmic proportions? This quirky take on a Transport for London Tube map has been designed by the astronomy team at the Royal Observatory Greenwich. Guaranteed to be the focus point of any room, this poster print will be a big hit with any astronomy or map-collecting fan. The poster is sold unframed and delivered in a poster tube. When laid flat it measures 70 by 50 centimetres (27.5 by 19.7 inches). The map is printed on 170gsm paper and has a matte finish.

FOR ADULTS & KIDS

CELESTIAL BUDDIES

Cost: $21.99 (approx. £15.99)

From: celestialbuddies.com

6 Have you ever wanted to give the entire Solar System a great big hug? Now you can with these adorably squishy celestial buddies. Each member of the Solar System has been transformed into a unique character, from feisty Mars to our loyal Moon. Even Pluto and Charon haven't been left out! Each buddy comes with its own little tag full of entertaining and interesting facts, making them both fun and educational. Pick your favourite planet or moon or collect the whole set so you can surround yourself with a soft Solar System.

HEROES OF SPACE

NORMAN E. THAGARD

The first American to board Mir, Thagard paved the way for the Shuttle-Mir program

Thagard is referred to as the first American cosmonaut

© NASA

When Thagard boarded the Mir space station alongside cosmosnauts Vladimir Dezhurov and Gennadi Strekalov, the culture of space exploration was changed forever. The mission demonstrated that space exploration and discovery was now well and truly a multinational enterprise.

Prior to the pioneering Mir 18 mission, Thagard only had one year of intense training under the Russian teaching system to prepare him for life on board Mir. Though Thagard was a seasoned Space Shuttle flyer, having flown on four previous Space Shuttle missions – as a mission specialist on STS-7, STS-51-B, and STS-30 and a payload commander on STS-42 – his stint aboard Mir be very different.

The training was intense, in Russian and on completely different systems. Thagard had to study the inner workings of both the Soyuz capsule and Mir, learning most of the experimental protocols as they were being developed. There was no room for error, and all exams needed to be passed before the department would allow Thagard to fly. Remarkably, Thagard and his fellow cosmonauts were only told they had passed all their exams and were permitted to fly just two weeks before the scheduled launch.

On the day of the launch Thagard was concerned about the weather, as he was used to launching from Florida in a subtropical climate. The Baikonur Cosmodrome makes for a very different experience, located on the desolate, windswept steppes of Kazakhstan. On launch day, a worried Thagard said to Strekalov, "Gennadi, we can't launch today. It's too cold," to which Strekalov replied: "The colder the better." Thagard then remarked: "Well all right, but it's still too windy." Strekalov replied: "As long as it's not a hurricane." Despite Thagard's reservations, the launch was a success, and the trio were soon on their way to Mir. Coincidently, NASA's STS-67 was also in orbit at the time of the launch, bringing the total number of people in space at the same time to 13, a new world record.

Thagard spent 115 days on Mir, though much of his planned research was delayed due to the Spektr science module arriving several months late. Spektr supported research into biotechnology, life sciences, material science and space technologies, and also enabled enhanced monitoring of Earth's natural resources and atmosphere. Regardless of setbacks, Thagard completed 28 experiments on Mir, and the crew returned to Earth aboard Space Shuttle Atlantis on 7 July 1995. The mission was a key component of the Shuttle-Mir program that was carried out between 1995 and 1998.

Born on 3 July 1943 in Marianna, Florida, Thagard demonstrated great ambition from a young age. At school he told his classmates that he wanted to be a medical doctor, a fighter pilot, an engineer and an astronaut. Incredibly, he actually went on to become all four.

Thagard received his bachelor's and master's degrees in engineering from Florida State University. He then joined the US Marine Corps in 1966, achieving the rank of Captain and flying 163 combat missions while serving in Vietnam. After the Vietnam War, Thagard returned to Florida State University to focus on a PhD in engineering. Already halfway through his childhood career list, Thagard then enrolled at the University of Texas Southwestern Medical School, earning his MD in 1977. In his early 30s, Thagard was already a medical doctor, a fighter pilot and an engineer. It wasn't long after that NASA selected him for astronaut training in 1978. After four Space Shuttle missions and a trip to Mir, Thagard left NASA and became a professor at Florida State University.

All About Space

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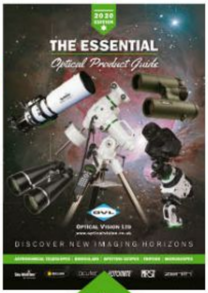

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